“The Fourth Agricultural Revolution: A US Policy Analysis for the Transition Toward Regenerative Practices”

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Spring 2025

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Abstract

There have been three major revolutions in agriculture in human history, and in the face of climate change and rapidly developing environmental destabilization, it is time for a fourth. This paper seeks to understand the state of current agricultural policies in the United States and their contributions to environmental degradation and the climate crisis, offering the alternative of regenerative agriculture as a holistic approach to restoring natural resources and environmental outcomes. Through a review of the scientific literature on the impacts of industrial agriculture and the relative improvements offered by regenerative approaches, a case for a regenerative transition is established. Regenerative practices are then outlined and assessed to provide a nuanced understanding of the promises and obstacles of this approach to agriculture. Finally, by unpacking and discussing current agricultural policy at a national and subnational scale, a series of suggestions are proposed to guide US agricultural policy in a more sustainable direction. A nationwide definition of the term regenerative will be a critical step in this transition, as well as developing robust financing instruments and incentives across scales, including state-level transition programs. With the most significant piece of agricultural legislation, the Farm Bill, up for review in 2025 with a set of policies to last until 2030, there is an urgent need to implement these policy suggestions to revolutionize American agriculture, making it more sustainable, resilient, and equitable.

Keywords

Food systems, agriculture, regenerative agriculture, sustainable food systems, US policy, Farm Bill, agricultural policy, policy recommendations, land use, farming

Introduction

"*The history of American agriculture suggests that you can have transformation without a master plan, without knowing all the answers up front*"[1]

Atul Gawande

American public health researcher, author, and Assistant Administrator of USAID

(1965–)

1.1 Overview of the Global Food System

As a species, we are dually blessed and cursed with maintaining near-total control over our food supplies; nearly 10 million metric tons of crops alone are produced each year (Lavagned Ortigue, 2022), and yet despite this, as a global society, our food system is rife with issues, inequities, and inefficiencies. Food is simultaneously personal and political, scarce and in excess, overproduced and underutilized; the modern global food system has become characterized by contradictory dualities. Even as food remains a hallmark of human cultures and a critical foundation for our survival, nearly one in ten people are faced with hunger, totaling almost 800 million (FAO, 2023). As the global population continues to increase, with projections of crossing 10 billion people in this century (United Nations, n.d.), food production will remain critical. Setting aside the major problems of food security and access, the way in which food is produced continues to engender the global climate crisis, in addition to other key functions of the planetary system.

[1](Gawande, 2009)

The modern food system is the product of millennia of civilization, industrialization, globalization, and extraction. It is also a testament to the success and prosperity of the human race and its ability to shape its environment to support the proliferation of our species. Beginning approximately 10,000 years ago (though estimates vary), human societies across the globe began to transition away from nomadic hunter-gatherer societies to more sedentary communities (*History of Agriculture*, n.d.). This transition is largely thought to be due to the advent of agriculture, which in the early stages consisted of the simple cultivation of crops and the beginnings of animal husbandry. Independently arising in fertile and productive regions on multiple continents, agriculture is thought to have provided the basis for early human civilization, enabling denser populations and a constant inhabitation of territories that could then expand. Additionally, the growing availability of calories and a decrease in the amount of time dedicated to finding food for survival enabled the human species to spend time developing increasingly advanced technologies. To some anthropologists and scholars of human history, this transition classifies the beginning of the Anthropocene (Gowdy & Krall, 2013), a term used to describe the present "Age of Humans" as the impact of the species leaves long-term geological and climatological markers on the planet.

Following the early beginnings of agriculture, major technological innovations like crop irrigation and the plow enabled civilizations to prosper, rapidly expanding in their development and size. It is these same innovations, though, that plowed the seeds of destruction, as they mark the beginning of what is now a multi-millennia problem of resource depletion and soil degradation, laying lands fallow and fruitless, and contributing to the collapse of several major civilizations, including the Roman Empire. Identified as early as 1940 by Sir Alfred Howard, "Judged by the ordinary standards of achievement the agricultural history of the Roman Empire

ended in failure due to inability to realize the fundamental principle that the maintenance of soil fertility coupled with the legitimate claims of the agricultural population should never have been allowed to come in conflict with the operations of the capitalist" (Howard, 1940, p. 17). The constant drive to not just produce as much as possible but also in the least expensive way possible quickly exhausted the natural fertility of soils, creating a crisis for large immobile civilizations, and ultimately contributed to their demise. Having identified the importance of sustainable and non-extractive agriculture nearly a century ago, what is the state of today's global food system?

1.2 A Brief History of Agriculture

Understanding the complex and interconnected nature of today's global food landscape requires a recapitulation of what came before, or in other words, everything that came between the first seeds of grain placed by human hands and the industrial network of trade and technology that feeds the global population today. On par with major milestones in human history like fire and walking on two feet, agriculture transformed the trajectory of the human race (Carey, 2023). This innovation altered the entire nature of human lifestyles, moving from nomadic and hunter-gatherer lifestyles to permanent settlement, a change "made possible only by the development and adoption of early agricultural practices" (Thrall et al., 2010, p. 405).

Formally identified as the Neolithic or First Agricultural Revolution, characterized by the domestication of plants and animals as well as "sedentism, population growth, and colonization of new areas" (Hole, 1984, p. 49), this revolution was facilitated by several optimal climatic and environmental factors, allowing it to occur roughly simultaneously in disparate regions (Simmons, 2011). There are several schools of thought on what exact conditions were necessary

for this revolution to arise, but the result is the same; in each instance where agriculture emerged, so did a "pattern of progressive development resulting in increasing cultural complexity" (Svizzero & Tisdell, 2014, p. 1). The simplest explanation for this is economic, having to do with the freeing of time and labor to direct to those needs that come secondary to survival; "the food surplus that early farmers were able to generate, for the first time in human history, made possible the establishment of a non-food producing sector" (Weisdorf, 2005, p. 564). Importantly, this began to reduce the direct connection between people and their food, initiating a trend of distancing producers from consumers. On a longer time scale, this trend created the environment and technologies necessary for the eventual Industrial Revolution.

The Industrial Revolution represents an additional major milestone in the relationship between human development and agriculture. Before discussing the importance and impact of industrialization, it is necessary to consider the "Second" Agricultural Revolution, which depending on the source, variably precedes or coincides with the Industrial Revolution, although the term revolution itself is a misnomer, as it is truthfully a series of gradual changes in practice and technology (OER Commons, n.d.). Regardless of the nomenclature, this transition is generally cited as having begun in Britain (although with time these practices began to be adopted and implemented in different countries around the world [Allen, 2000]), and was twofold, "first, an unprecedented increase in agricultural output brought about by an equally unprecedented increase in land productivity, and, second, an unprecedented increase in labour productivity which was a necessary corollary to industrialization" (Overton, 1996, p. 1). These major improvements in yield and productivity had a similar impact to the First Agricultural Revolution, once again generating a large food surplus and reducing labor demands, allowing for a greater shift in attention toward technology and industry. New strategies in agriculture like

planned crop rotation and advancements in tools, both new and old "including the plough, seed drill, and threshing machine" (OER Commons, n.d., para. 6), further increased yields and the ease with which agricultural productivity could be improved without additional labor. Crop rotation is especially important, despite the relative simplicity of the practice as "the production of different economically important plant species in recurrent succession" (Aflakpui, 2012, p. 25), or in other words, growing different crops on the same fields in succession to avoid exhausting stores of nutrients and minerals in the soil.

The Industrial Revolution, then, expanded upon this second Agricultural Revolution, as more and more people were able to move to cities in rural-to-urban migration as food became readily available across nations (OER Commons, n.d.), moving the needle forward in social organization and technological advancement. In the following decades the global population boomed, putting increasing pressure on food production and driving huge changes in technology and practices, with modern production of staple crops alone totalling over 3 billion tonnes in 2022, as shown in Figure 1. This subsequent suite of innovations can be classified into the Third Agricultural Revolution, also known as the Green Revolution.

1.3 The Green Revolution

While each of the previous milestones in the development of human agricultural practices has been profoundly impactful on global human societies, it is the most recent "Green Revolution" which produced some of the greatest changes, exponentially increasing global food production while also simultaneously facilitating the rapid exhaustion of productive land and the introduction of corporate monoculture agriculture. As with the Second Agricultural Revolution, the exact timeline of this revolution is disputed among scholars, some placing it as 1966–1985

(Pingali, 2012), while others hold a broader definition spanning as far back as 1941 when the Rockefeller Foundation began surveying agriculture in Mexico (Patel, 2013). Roughly, the Green Revolution began during and in the wake of the Second World War, when scientists and chemists began to seek alternative uses for nitrogen used in explosives and turned to its application as a plant fertilizer (Union of Concerned Scientists, 2023). Although experimentation with techniques developed in warfare began in the 1940s, the widespread distribution and application of synthetic fertilizers didn't truly take hold until the 1960s.

Regardless of the exact timeline, the Green Revolution was an institutional overhaul of agricultural practices, driven "as a result of US and philanthropic funding for fertilizer, irrigation, improved hybrid seeds, state support and credit" (Patel, 201, p. 5), resulting in "an extraordinary period of food crop productivity growth…despite increasing land scarcity and rising land values" (Pingali, 2012, p. 1). As with the prior two revolutions, the landscape of food production was transformed, with a further scaling up of farms and yields, and an increase in the distances between food, producers, and consumers. Important to note in this third major agricultural transformation is the scope, where impacts broke new horizons, particularly among emerging economies which experienced more than a doubling of food production from 1960 to 1985 (Patel, 2013). This marked a turning point, where global food production had now entirely caught up with and even surpassed population growth, meaning more than enough food was being produced to feed the world population (yet hunger did not disappear, and remains a pressing global concern).

As mentioned, synthetic fertilizer, national and international investment and involvement, and genetic engineering of staple crops should have created security in the global food supply. However, the persisting prevalence of global food-related concerns reveals this is not the case–

famines, food insecurity, health crises, zoonotic diseases, resource depletion, and natural disasters including drought, erosion, and wildfire all can be tied back to complications of the modern global food system. From an economic and productivity point of view, the Green Revolution "seems to have succeeded amply" (Patel, 2013, p. 6). The truth of today's food system is far more complicated.

1.4 Agriculture in the Modern Day and the Need for Reform

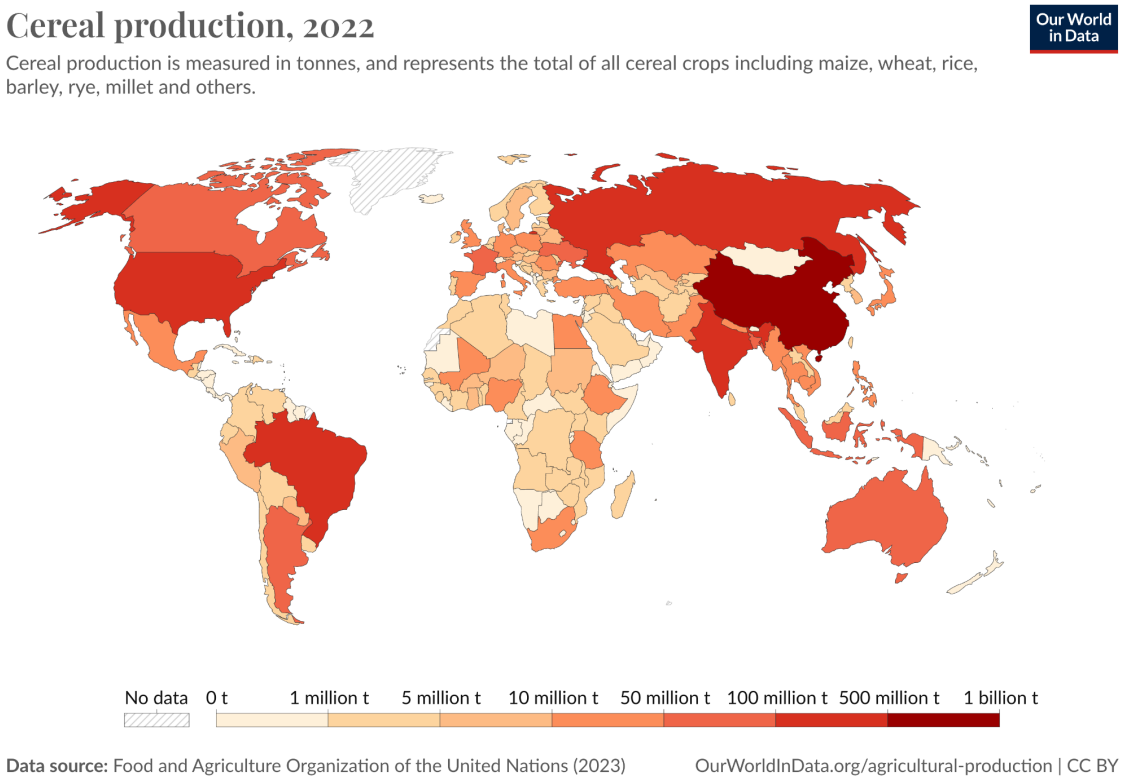


Figure 1. Global production of staple crops as of 2022, totaling over 3 billion tons, more than triple the amount produced in 1961, just over 60 years ago. Reprinted from "Agricultural Production," by H. Ritchie, P. Rosado, and M. Roser, 2023, *Our World in Data* (https://ourworldindata.org/agricultural-production). Licensed under CC BY 4.0.

Political theorists that have studied food politics have classified different periods throughout human history into different "food regimes." These regimes are intrinsically related

to global and national power dynamics at various points in time and can be defined as "a particular pattern of specialization and trade in which the world economy, a particular system of power including which government, which state, is dominant or hegemonic, particular kinds of farming systems and crops, which are leading the change and the dynamism of the system and modes of consumption" (Friedmann, 2014, p. 1). These regimes largely coincide with the major agricultural revolutions already discussed, including a settler colonial regime through the period of the Industrial Revolution, a transition regime through WWI and WWII, and the emergence of an industrial food regime alongside the Green Revolution (Friedmann, 2014). Subscribers to this theory have determined that global society now finds itself amidst a "Global Food Crisis" (Sommerville et al., 2014), made evident by the role food has played in recent major world events, catalyzed by a series of food riots in response to rising prices and increasing geopolitical tensions in 2007-2008 affecting many countries across the globe (McMichael, 2009). As part of a change in market and power structures, the global food system now finds itself in a "corporate regime," in which "neo-liberalization and privatization combine to accelerate food circulation globally and restructure food production and retailing along corporate lines" (McMichael, 2009, p. 290).

What are the consequences of this "corporate regime"? The current period of uncertainty in the global food system, "driven by familiar ills…coupled with deepening global inequalities" (Sommerville et al., 2014, p. 242) is overdue for a course correction. While the challenges and consequences of current systems of food production are deeply intersectional and complex, this investigation focuses on the deep and pervasive environmental impact of modern food production. Drawing on the planetary boundaries introduced by Rockström et al. in 2009, fundamental and critical natural processes that if disturbed beyond a threshold "could generate

unacceptable environmental change potentially endangering human existence" (Campbell et al., 2017, p. 7), agriculture is a major threat to crossing crucial tipping points.

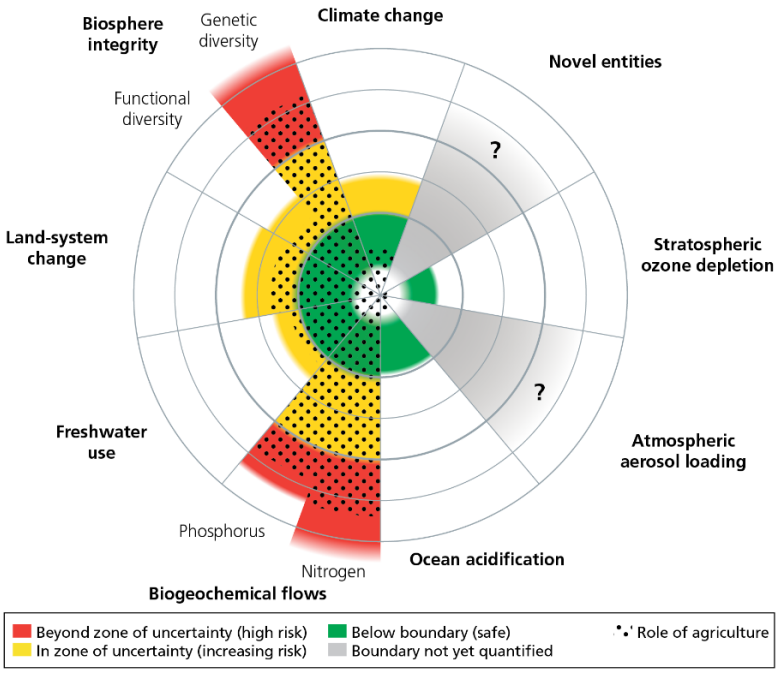


Figure 2. Depiction of the role of agriculture in contributing to the threats to the nine planetary boundaries. Reprinted from "Agriculture Production as a Major Driver of the Earth System Exceeding Planetary Boundaries," by B. M. Campbell, D. J. Beare, E. M. Bennett, J. M. Hall-Spencer, J. S. I. Ingram, F. Jaramillo, R. Ortiz, N. Ramankutty, J. A. Sayer, & D. Shindell, 2017, *Ecology and Society, 22(4)*. https://www.jstor.org/stable/26798991. Copyright 2017 by the authors.

As shown in Figure 2, agriculture plays a major role in the exhaustion and disruption of biogeochemical flows of key nutrients (nitrogen and phosphorus), due in large part to chemical fertilizers and other synthetic inputs. It is also one of the largest drivers of land-system change, where expanding agriculture "has caused a net loss of ~7 to 11 million km^2 of forest in the past 300 years" (Campbell et al., 2017, p. 2), a major disruptor of the integrity of the biosphere, and a significant contributor to climate change and freshwater use. Sustainable agricultural reform is critical, and urgent, for without immediate and effective action, "our planetary environment may severely deteriorate in the future due to widespread deforestation, nearly doubling of current

emission levels of GHG from agricultural production and high losses of N and P to freshwaters and oceans" (Conjin et al., 2018, p. 2).

1.5 Regenerative Agriculture: The Fourth Agricultural Revolution?

In the face of current systems, sustainable policy reform must be attainable, equitable, and effective at improving the environmental impact of US food production. Defining and delineating what practices qualify as sustainable is remarkably complex, and has major political, social, and economic implications for both food producers and consumers. In recent years, the term regenerative has emerged as an aggregation of various movements and methods of approaching food production. Definitions of regenerative agriculture vary but can generally be summarized as an approach to agriculture that diverges from present industrial agriculture practices and reframes food production practices as a philosophy of land management with key tenets including protecting soil health, minimizing inputs, and focusing on the relationships between elements of natural systems.

It is important to acknowledge early in any discussion of regenerative agriculture as a counter to industrial agriculture that, while this has not been implemented in the history of the US, it is not a new practice to this land. From an Anglo-American perspective, this may appear to be the case, but Indigenous agricultural practices and methods of food production carry many of the same principles touted by present-day advocates for regenerative agriculture (Heim, 2020). Intercropping, agroforestry, natural resource management, and permaculture are all practices and approaches to agriculture that are used by regenerative producers and have long been established among Indigenous communities and populations around the world. To treat regenerative agriculture as a novel solution is to ignore millennia of traditional indigenous knowledge and to

further perpetuate settler-colonial violence against indigenous peoples. Terming regenerative agriculture as the Fourth Agricultural Revolution may thus appear to be a misnomer, but in the context of this paper, it may be more accurately understood based on its etymological origin, from the Latin *revolvere*, meaning to "roll back...happen again" (Online Etymology Dictionary, n.d.), reconceptualized as a return to practices the food system has long since become detached from. An equitable and effective transition to regenerative approaches must acknowledge this complex and violent history leading to today's food system.

Building, then, upon those Indigenous practices established well before industrial agriculture and the so-called "corporate regime," regenerative agriculture offers an alternative to current approaches in that it reprioritizes the natural environment, holistically aiming to "restore soil and ecosystem health, addresses inequity, and leave our land, waters, and climate in better shape for future generations" (NRDC, 2021, para. 2). In doing so, regenerative agriculture offers a sustainable alternative to the current US method of food production. It is the purpose of this investigation to determine whether this is firstly feasible, not just in terms of yields and outputs, but also in economics for convincing actors, and secondly what existing and proposed agricultural policies may hold the most promise for driving US agriculture toward a more sustainable system of food production.

1.6 Conclusion

Regenerative principles are still on the margins of current agricultural practices, and although attention has been increasing toward the impacts of present agriculture on climate change and the environment, the rate at which understanding and action are proceeding is far behind what is needed. Urgent, effective, equitable, and sustainable reform must be made to US

agricultural policy to improve the domestic food system. To address the question of how to sustainably produce food at an effective scope of analysis, the complications of industrial agriculture are contrasted with the emerging alternative of regenerative agriculture in Chapter 1, noting scientific evidence against the former and supporting the latter in terms of environmental impact. In Chapter 2, the improved environmental outcomes under regenerative management are contrasted to the present model, laying out a case for a regenerative revolution. Additionally, questions of feasibility and scalability where further innovation and progress will be needed are identified and discussed. Finally, Chapter 3 analyzes existing US agricultural policies which both stand in the way of a regenerative transition and offer entry points for potential sustainable reform. Proposed policy changes are then offered to facilitate a transition to an agricultural system which is potentially more sustainable as a result of a regenerative approach.

Throughout this investigation, I strive to answer the question of how regenerative agriculture can be proposed and incorporated into existing US agricultural policy as a strategy for reducing the environmental impact of food production. Through a composite literature and policy review, additional discussion is given to analyzing the scales at which regenerative agriculture policy appears most effectively implementable, the practices that are most politically appealing and feasible, and the strategies by which these practices can be attached to economic or political incentives to encourage reform. This is followed by a series of recommendations for the large-scale implementation of regenerative agriculture in the US as a way to reduce national contributions to climate change. Beyond discussing existing action to further this mission, the Conclusion offers further insight into the scope or level at which agricultural policy is most effective, be it national, state, or local, as well as the potential incentives or strategies needed to pass policy that will produce urgent and impactful change.

Importantly, this discussion does not consider the differences between industrial animal agriculture and regenerative approaches to animal production. While this is a critical component of the conversation surrounding the sustainability of the American food system, there has yet to be sufficient and robust scientific evidence for how introducing livestock production to regenerative management affects environmental outcomes. Furthermore, the industries and policies surrounding animal agriculture are deeply complex, somewhat separate from crop producers, and beg the complicated question of behavioral shifts in consumption for improving sustainability. For the purpose of this investigation, the discussion of regenerative and industrial agriculture focuses primarily on crops and non-animal production.

In conclusion, this direction of research offers an alternative to the consumer-based approach that has become prevalent in advocating for a more sustainable food system, where the responsibility is placed on consumers to change their behavior and create economic and social pressure to drive change. While both are necessary, this investigation asserts that policy reform on the production side of the food system has been understated as a strategy for making sustainable change. The outcomes of this research thus represent not just a novel approach to constructing sustainable agricultural policy but also draw attention to a theory of change that has been underexplored and underemphasized within the broader context of the existing food system.

Chapter 1: Regenerative Agriculture vs. Industrial Agriculture: A New Framework for Food Production

"*It is an easy matter to destroy a balanced agriculture. Once the demand for food and raw materials increases and good prices are obtained for the produce of the soil, the pressure on soil fertility becomes intense. The temptation to convert this fertility into money becomes irresistible*"[2]

Sir Albert Howard

English botanist and pioneer of soil health in farming practices

(1873 – 1947)

2.1 Introduction

The US is one of the world's largest food producers, third behind China and India (Ross, 2024). Agriculture has been fundamental to the development of America and the American identity over the last 500 years, and yet soils and lands are rapidly being eroded and depleted, drought and water scarcity are becoming more widespread, and natural cycles are increasingly disrupted. In addition, as shown in Figure 3, the number of farms has plummeted since the beginning of the 20th century as the average size has increased, predominantly due to the advance of large-scale agriculture (USDA ERS, 2024a).

[2](Howard, 1940)

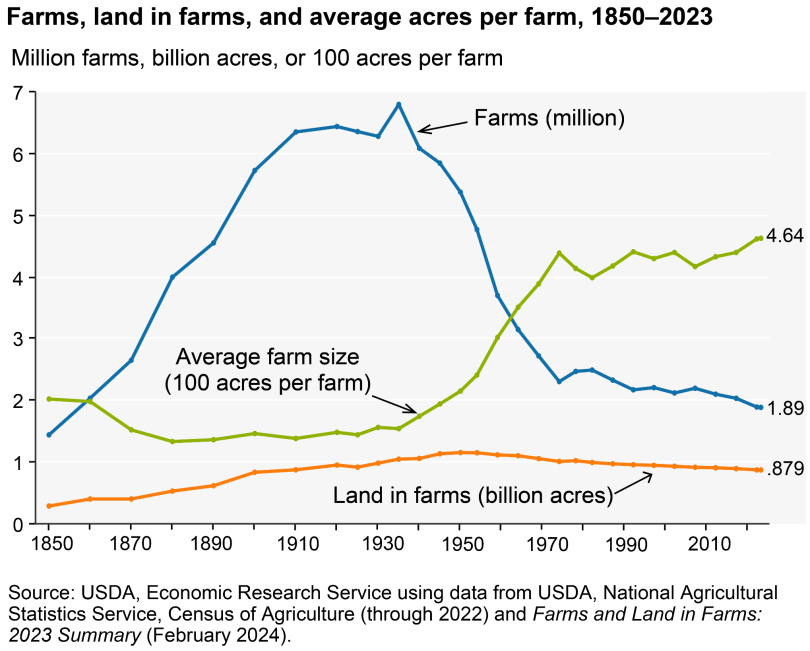


Figure 3. The number of farms in the US steadily increased through the 19th and early 20th century, peaking at 6.8 million before dropping to levels today comparable to the mid-19th century. Note the increase in average farm size since the 1940s. Reprinted from "The Number of U.S. Farms Continues Slow Decline," by A. Keller and K. Kassel, 2024, *Economic Research Service, U.S. Department of Agriculture*. (https://www.ers.usda.gov/data-products/chart-gallery/chart-detail?chartId=58268). In the public domain.

The American agricultural system is unique from that of other early industrialized nations because even in the infancy of the country there was already an emerging global market, making American agriculture commercial from the start (Conkin, 2008). While early colonial settlements did adopt some of the practices modeled by Indigenous people along the East Coast, such as introducing maize as a dominant cereal crop and utilizing land that had already been cleared, for the most part, they carried on the same practices used in Europe for centuries. Despite arriving in a completely different environment, with unique species compositions, weather patterns, soil types, and suitability for agriculture, early agriculturalists imposed a foreign method of food production without considering the new context in which they found themselves. This would,

eventually, become a critical distinction underlying the approaches of industrialized and regenerative agriculture.

In the first century of European settlement in the New World, agriculture played a major role in the colonial economy, with “nearly all of the first colonists engaged in farming”, a trend which continued through the beginning of the fight for American independence, at which point “approximately 75 to 90 percent [of colonists] still practiced agriculture” (Hurt, 2002, p. 35). An abundance of cheap, uncultivated land alongside a loss of competition from Indigenous peoples due to genocide and disease enabled the rapid growth of agriculture in the early US. This land was promptly bought up and then clear-cut in a wave of expansion inward from the Eastern seaboard. In the early stages, colonial farmers practiced crop rotation, although as fields became depleted they simply cleared more land and started anew (Hurt, 2002), leaving behind landscapes that had been deforested of native vegetation, depleted of nutrients and soil fertility, and left disturbed and susceptible to a fleet of introduced species. Even as collective understandings of ecosystem processes and agriculture improved through the 18th and 19th centuries, early American agriculturists remained “governed by the potential for economic gain” (Hurt, 2002, p. 37). It is worth noting that many of those crops that remain most produced by current American farmers began in the 17th and 18th centuries, notably corn and wheat, but also non-food crops like tobacco and cotton, which are inseparable from early American agriculture, especially in the South (Fite, 2014).

As highlighted in the Introduction, agriculture underwent a series of revolutions during the timespan of America’s development. With The Homestead Act of 1862 and westward expansion into the Great Plains, “The Breadbasket of America,” came an untapped region for producing staple crops, and settling of the West Coast further opened the door for vegetable

production in California. Industrialization allowed for a period of exponential growth in crop yields, and the US's rising global influence through the 19th and 20th centuries allowed for a further expansion of agricultural exports. Important to note in considering the history of agriculture is the events of the early 20th century, characterized by both the Great Depression and the Dust Bowl, which exposed for the first time some of the major underlying flaws of US agricultural policy.

2.1.1 Case Study: The Dust Bowl, an American Agricultural Disaster

The roots of the Dust Bowl crisis can be traced back to a variety of practices and policies, both those that contributed and that attempted to mitigate, such as the 1916 Federal Farm Loan Act. This act created a network of regional land banks that enabled farmers to borrow and build credit, enabling greater investment in new technologies, a change that became critical in supplying food during the ongoing war at the time (Gregg, 2015). As stated in the opening of the act, it served:

> To provide capital for agricultural development, to create standard forms of investment based upon farm mortgage, to equalize rates of interest upon farm loans, to furnish a market for United States bonds, to create Government depositories and financial agents for the United States, and for other purposes (Fletcher, 1916, p. 1).

The result of this act was millions of dollars of investment into the rapid expansion of agriculture, funding "the purchase of machinery, the consolidation of farms, and the unprecedented expansion of wheat acreage during World War 1, a confluence of events known as the Great Plow-Up" (Gregg, 2015, p. 130). Largely a result of focused attention toward the ongoing conflict in Europe, American agriculture was transformed, with little forethought granted to the economic and ecological consequences of such rapid change. While producing at

such a great rate and volume was a major advantage during the war, as the conflict came to a close in 1918, American producers did not slow down, generating annual surpluses which rapidly created economic concerns entering the 1920s. Despite attempts such as the Wheat Stabilization Act of 1919 to mitigate a burgeoning agricultural crisis, which "appropriated $1,000,000,000 [over $18 trillion in today's value] to make previous commitments effective until June 1, 1920" (Shideler, 2022, p. 23), as European economies stabilized and food production overseas recovered, American farmers were rapidly producing more food than could be purchased and prices plummeted (Enfield, 1924). A compounding of overproduction, hasty policy, and ecological disruption carried this crisis over into the Great Depression which plagued the nation through the 1930s.

Coincident with and contributing to the Great Depression was a period of intense drought, climatologically connected to La Niña, a phase of the El Niño Southern Oscillation which occurs every 2-7 years, temporarily shifting the jet stream northward and bringing about dry conditions across the Southern portions of the US (Clark et al., 2014). This alone would already have been a challenge for growers and food producers in the region, destabilized by the economic crisis. Unfortunately, the mainstream practices of the time further contributed to this extreme climate event. While the La Niña event associated with the Dust Bowl was especially severe, historical analysis shows that "human-induced land degradation is likely to have not only contributed to the dust storms of the 1930s but also amplified the drought" via compounding eroded soils and decreased water retention, which "turned a modest SST-forced [Sea Surface Temperature] drought into one of the worst environmental disasters the U.S. has experienced" (Cook et al., 2009, p. 4997). Several practices contributed to this land degradation, from tillage erosion to industrialization to simply poor farming practices, but the impact overall was to

effectively degrade the soil, leaving it dry, nutrient deficient, and especially sensitive to drought (Baumhardt et al., 2015).

With a reduced ability to retain water, and a lack of natural vegetation cover to provide roots to hold soils in place, the extreme effects of La Niña were amplified, an overall crisis that "created widespread hardship, bankrupted many local governments, propelled high rates of farm abandonment and out-migration, and stimulated dramatic changes in government agricultural, land management and socio-economic policies" (McLeman et al., 2014, p. 422). Notably, while these climate effects crossed national borders and extended their impacts north into Canada and South into portions of Mexico, the central area of impact was the Great Plains, due to a combination of their unique landscape and soil type as well as the antiquated forms of agriculture practiced by farmers. This left Mexico largely unaffected given its different ecology and system of food production, save for an influx of Mexican farmworkers who, without the work of American agriculture, returned home to pursue other ways of making a living (Library of Congress, n.d.). Canada felt similar impacts as their southern neighbor, for although they experienced a lag in the process of agricultural development relative to the US, by the early 20th century they had similar homestead policies and land use patterns (McLeman et al., 2014).

The case of the Dust Bowl and its inherent connection to the Great Depression thus presents a historical case study for the dangers of industrialized agriculture and its sensitivity to both economic and ecological disturbance. It also provides evidence against the system still in place today, as highlighted by the failure of a host of agricultural policies enacted to mitigate this crisis. The lessons of the Dust Bowl and its massive impacts on the economy and food security emphasize a long-standing need for change.

2.2 The State of Industrial Agriculture

It has been nearly a century since the events of the Dust Bowl contributed to a nationwide crisis, stemming from both the most severe period of drought and the most intense economic depression in US history. Still, the state of industrial agriculture today has yet to learn from the crises of the past, with little change to underlying approaches to large-scale food production in the US. This is not to say that American agriculture has somehow failed; farms are more productive than ever (Burchfield et al., 2022), and national food security is ranked 13th in the world on the Global Food Security Index (*Global Food Security Index*, 2024), especially significant given that the US population is triple that of any country with higher food security (*Population by Country*, 2024). Rather, the argument made in this chapter and broader paper highlights the *inefficiencies* of the US agricultural system, with a critical lens on its negative environmental impacts.

To understand the most explicit threats to the domestic and global environment, four key indicators can be used as a means of assessing the environmental impact of US agriculture: land use, greenhouse gas emissions, freshwater use, and nutrient cycles. These are drawn from the planetary boundaries model mentioned in the Introduction, as key indicators of global impacts which the food system has severely altered. Assessments of these global values from 2010 are estimated as "the equivalent of 5.2 billion tonnes of carbon dioxide in GHG emissions in the form of methane and nitrous oxide; the food system also occupied 1.6 million km^2 of cropland, used 1,810 km^3 of freshwater resources from surface and groundwater (bluewater), and applied 105 teragrams of nitrogen (TgN) and 18 teragrams of phosphorus (TgP)" (Springmann et al., 2018, p. 520). The following sections will break down the importance and extent of each of these criteria to further demonstrate the impacts of industrial agriculture on the environment.

2.2.1 Land Use

Agriculture occupies roughly 40% of the Earth's terrestrial surface area and over 400 million hectares of land in the US (Rathore et al., 2022; Ritchie & Roser, 2019), representing 44% of the total US land area, just above the global average. On the global scale, "the expansion of land under agriculture has caused a net loss of ~7 to 11 million km^2 of forest in the past 300 years" (Campbell et al., 2017, p. 2). From an environmental perspective, this has severe implications for biodiversity loss and the protection of areas containing natural resources that provide key ecosystem services. Additionally, changes in land use have not just ecological, but also economic impacts: "Consequences from land use changes are diverse and affect the overall productive capacity of land to sustain future supplies of both environmental services and primary products to the economies" (Gurgel et al., 2021, p. 1). Agriculture is the primary driver of biodiversity loss on a global scale due to its conversion of natural habitats into cleared lands used to support a very small number of species (UNEP, 2021), and as a result of further indirect impacts of agriculture "including through energy use, transport and waste" (Dudley & Alexander, 2017, p. 45). Considering trends of warming from climate change, this form of human land use is expected to expand further north in the US (see Figure 4) into some of the few remaining uncultivated areas in the central region of the country (Cunningham, 2022).

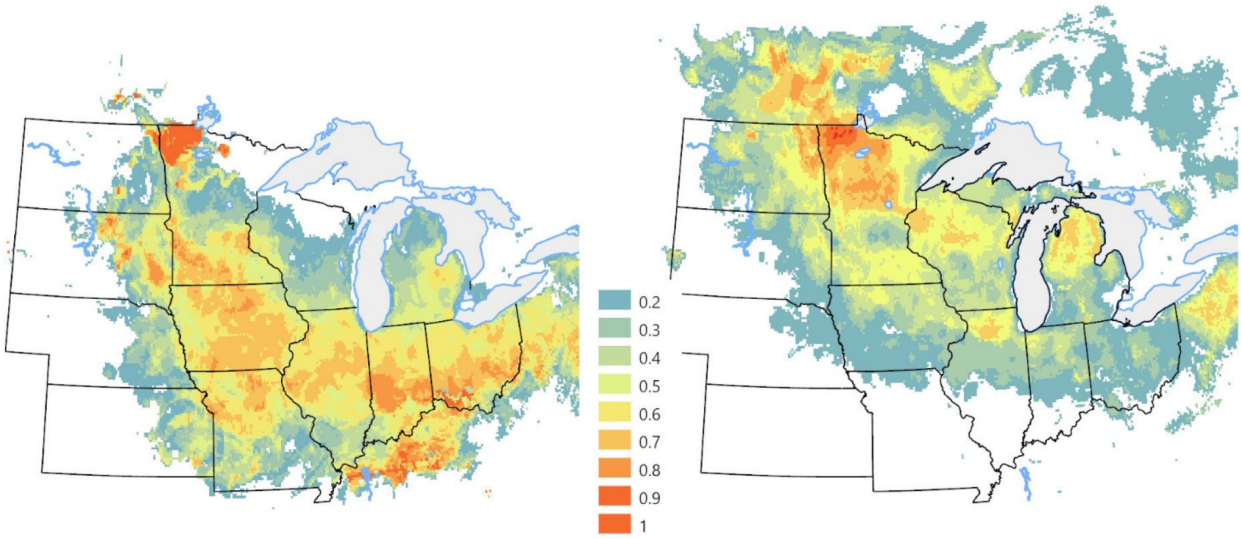


Figure 4. Climate suitability model for recent agricultural conditions for staple crops like corn, (left), and projected suitability in 2050 (right). Suitability values, range from 0 (unsuitable) to 1 (highly suitable). Reprinted from "Climate Change, Agriculture, and Biodiversity: How Does Shifting Agriculture Affect Habitat Availability," by M. A. Cunningham, 2022, *Land, 11*(8), Article 8 (https://doi.org/10.3390/land11081257). Licensed under CC BY 4.0.

Despite the significant proportion already in use, projections for global land use for agriculture show increases, with one study identifying "the area in crop production increases from 1.4 billion ha (or 10% of Earth's land surface) to up to 2.3 billion ha" (Smith et al., 2010, p. 2949). Interestingly, land use for agriculture in the US has been gradually decreasing in the past decades. From a sustainability perspective, this trend is promising if more efficient and ecologically oriented use of land can maintain sufficient volumes of food production with the caveat of reducing environmental impact, as will be discussed shortly. However, the way existing agricultural land is managed and farmed has significant implications for its emissions, environmental impacts, and long-term sustainability. Given the uncertainty of future projections of climate change and land use for agriculture, there is an increasing need to investigate and question the ways in which limited national land resources are being used, especially for industrial agriculture which can highly modify natural landscapes.

2.2.2 Greenhouse Gas Emissions

Reduction of greenhouse gas emissions is one of the most direct and impactful ways to address climate change and secure a sustainable future for the planet and future generations. The US is one of the world's top emitting countries, second only to China (6001.2 $MtCO_2e$ and 12,705.1 $MtCO_2e$ respectively as of 2023), but with a quarter of the population (Friedrich et al., 2023). Globally, agriculture is a contributor to up to 30% of greenhouse gas emissions according to the IPCC, contributing not just CO_2 but also methane (CH_4) and nitrous oxide (N_2O) (Tubiello et al., 2013).

According to estimates from the EPA in 2021, US agriculture "emitted 312.6 MMT as nitrous oxide (N2O), 278.4 MMT as methane (CH4), 44.7 MMT as on-farm carbon dioxide (CO2), and 35.7 MMT emitted indirectly through the electricity that the agricultural sector uses" (Sands, 2024, para. 1), representing over 10% of national GHG contributions. While this may seem like a fairly small proportion, these values need to be put in context. On the global scale, agriculture is the second largest contributor to greenhouse gas emissions, second only to the energy sector, making it a suitable target for mitigation through emissions reduction. Policy attention has been steadily growing to this sector, with proposals like the Agriculture Resilience Act of 2023 incorporating considerations for GHG emissions explicitly as an urgent concern, proposing to "set national goal of a minimum 50% reduction in GHG emissions compared to 2010 by 2030 and net-zero by 2050" (Sen. Heinrich, 2023, p. 3). With increasing domestic and international pressure for countries, especially wealthy developed nations like the US, to reduce their emissions to net zero, agriculture represents a major area for improvement.

2.2.3 Freshwater Use

Of the four criteria highlighted here, freshwater use is perhaps the most directly and significantly impacted by agriculture, given that "Of all human activities, agriculture, and specifically crop production, consumes the largest amount of water, mainly via transpiration from crop plants and evaporation from soils and irrigation structures" (Campbell et al., 2017, p. 3), accounting for roughly 70% of withdrawals at the global scale. This global trend is anticipated to fluctuate regionally over the coming decades as agriculture practices shift and populations change, suggesting pressures may be increasing. The US exemplifies this trend, as of 2012, "agriculture accounts for 80-90 percent of the Nation's consumptive water use (water lost to the environment by evaporation, crop transpiration, or incorporation into products)" (Schaible & Aillery, 2012, p. i). This should be a clear cause for concern considering freshwater supplies are an inherently limited resource, whose exhaustion could lead to local and regional depletion (Gleick & Palaniappan, 2010).

Groundwater depletion is an example of how agriculture is impacting the distribution and natural cycling of water through ecosystems, one that is expected to increase with the compounding pressure of climate change making irrigation increasingly necessary as precipitation patterns change. A direct result of pressure on farmers to produce high yields, "has led to unsustainable use of water resources in many locations" with climate change "expected to increase [water resource use] by more than 50%" in some regions (Haqiqi et al., 2023, pp. 2,9). The case against industrial agriculture is strong when assessed by this criteria, as "despite technological innovations, at least half of U.S. irrigated cropland acreage is still irrigated with less efficient, traditional irrigation application systems" (Schaible & Aillery, 2012, p. i).

Patterns of drought and increased water scarcity in the Western US demonstrate the importance of reform in the agricultural use of freshwater resources. A study on irrigation on farms and ranches conducted in 2008 identified that "irrigated agriculture across the Western States applied 74 million acre-feet (24 trillion gallons) of water for crop production, with 52 percent originating from surface water sources and 48 percent pumped from wells that draw from local and regional aquifers" (Schaible & Aillery, 2012, p. iii). As temperature rises and precipitation patterns shift in this region, natural cycles of snowmelt and timing of freshwater flows are expected to shift as well, further disrupting current supply patterns and misaligning with summer and fall growing seasons, exactly when peak irrigation is necessary.

Lastly, developments in ecological understanding in the past decades have increased the pressure on water use through establishing an environmental flow standard, which acknowledges a minimum need for natural cycles to be uninterrupted to accommodate ecosystem habitats (Schaible & Aillery, 2012). Largely to accommodate minimum stream flows to support native fish species, increasing political attention has been directed to this standard, further driving restrictions on already scarce freshwater resources, especially in Western states. With pressures to reduce freshwater depletion for agriculture for climatic, ecological, energy, and efficiency purposes, industrial agricultural practices must seek new approaches to water management.

2.2.4 Nutrient Cycles

The final criterion through which the environmental inefficiencies of agricultural practice in the US are demonstrated is the impact of current practices on nutrient cycles, specifically nitrogen and phosphorus. As touched on in the Introduction, nitrogen and phosphorus are critical components of biogeochemical flows in natural ecosystems which have become increasingly disturbed as a result of industrial agriculture (Campbell et al., 2017; Guignard et al., 2017).

These two nutrients play a critical role in plant productivity, forming a majority of the NPK triad (alongside potassium), the three primary elements needed for plants to grow, feeding directly into the development of the Haber-Bosch process that allows for the generation of synthetic ammonia for use as a fertilizer (Hergert et al., 2015). The deployment of synthetic fertilizers loaded with these elements at first seemed a boon to agriculture, as further improvement and development of the generation processes through the two World Wars contributed heavily to the Green Revolution. Over time, though, this practice led to dependency, driving a positive feedback loop of "long-term overreliance on chemical fertilizers and other industrial farming methods…creating a vicious cycle in which farmers apply even more chemicals" (Union of Concerned Scientists, 2023, para. 7).

Furthermore, the heightened application of these chemicals has not been entirely successful, with huge volumes of fertilizer being carried out of agricultural land by runoff, where they severely disrupt natural ecosystems. In the US, research has demonstrated that "nearly two-thirds of the nitrogen we use on our crops becomes a pollutant; more than half of applied phosphorus does" (Ritchie & Roser, 2024, para. 2). This is a huge cause for concern, threatening not just natural ecosystems, but also the wellbeing of entire communities.

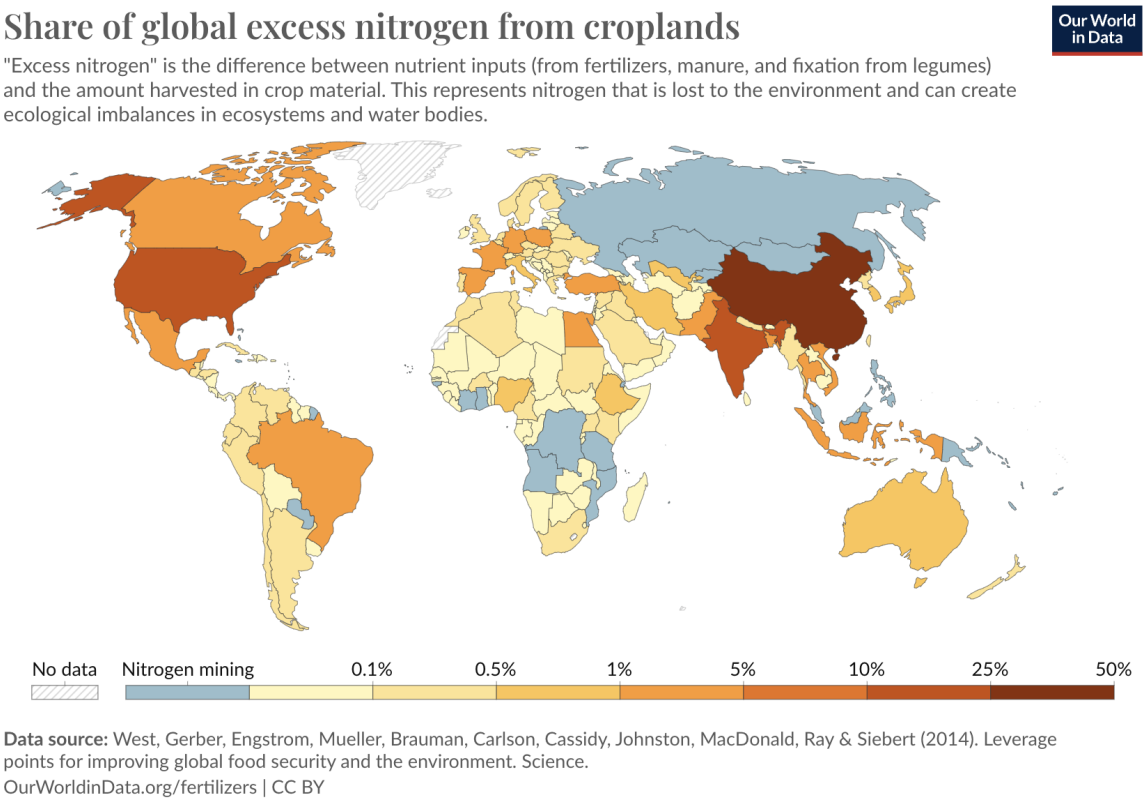


Figure 5. Demonstrates the percentage of applied nitrogen that is lost to the environment from cropland across the globe, with the US being one of the top three contributors. Reprinted from "Land Use," by H. Ritchie & M. Roser, 2019, *Our World in Data* (https://ourworldindata.org/land-use). Licensed under CC BY 4.0.

Figure 5 above highlights the inefficiencies exhibited by industrial agriculture and its contribution to disrupted biogeochemical cycles, wherein globally "approximately half of the N applied to croplands is incorporated into plant biomass, while the remains are lost" (Campbell et al., 2017, p. 4). Critically, the nitrogen that is lost as a result of agricultural production has severe environmental implications, namely for its principle role in driving eutrophication of natural ecosystems. Eutrophication occurs in aquatic and marine ecosystems as a result of heightened or excess nutrients, which in turn causes booms in productivity, as exhibited in algal blooms, and can be a primary driver of hypoxia, or a depletion of oxygen (Chislock et al., 2013). This trend is directly harmful to water quality and aquatic ecosystems by rapidly altering environments but

also poses threats to human society due to the production of toxins by blooms of cyanobacteria and the endangering of fisheries as a result of 'dead zones' of depleted oxygen and excessive productivity (Chislock et al., 2013). Industrial agriculture thus once again demands urgent attention to reduce its pressure on biodiversity, the environment, and human purposes– including public health.

2.3 Understanding Regenerative Agriculture

Judging by these environmental criteria, the current industrial agriculture system in the US is fundamentally untenable, and actively threatens and harms not just the environment, but biodiversity, human health, and planetary wellbeing. Regenerative agriculture offers an alternative framework to industrial agriculture that addresses these environmental impact criteria, while also offering a methodology that emphasizes the *interconnectivity* of human agriculture with natural ecosystems. Whereas industrial agriculture is generally imposed onto a natural environment, with the removal of obstacles through deforestation and heavy tillage, the input of chemicals to stimulate productivity, and little consideration for externalities, regenerative agriculture fundamentally functions *within* the natural environment. The precise principles and practices included under the umbrella of regenerative agriculture will be discussed in the next chapter. Understanding the history and emergence of regenerative agriculture, first, is important for providing context and grounding the practice in concrete terms for policy integration, and understanding how it differs from industrial agriculture.

2.3.1 Emergence of Regenerative Agriculture

While the practices advocated for in regenerative agriculture are not novel, the field as a whole is relatively new, emerging under the nebulous idea of "regeneration" in the last 50 years (Soloviev & Landua, 2016). Its application to agriculture and food production was pioneered by the Rodale Institute, which began to use the term "regenerative organic agriculture" in the 1970s to advocate for a new way of considering agriculture which focuses on maintaining and improving the state of the ecosystem in which food production occurs (Shearer, 2019). The emergence of regenerative agriculture was part of a larger trend across the globe, with increased environmental awareness and concerns about the use of chemicals in food production becoming a subject of attention. IFOAM, the International Federation of Organic Agriculture Movements, emerged in 1972 in response to these and other concerns and characterized a series of movements within the agricultural sector, including organic farming, no-till practices, agroecology, and permaculture (all practices that incorporate regenerative principles) (Leu, 2020). With increased attention affixed to improving agricultural practices, the Rodale Institute, under the leadership of Robert Rodale, coined the term regenerative organic agriculture as a way of going beyond sustainable agriculture, the key distinction being long-term improvement (consider the difference between striving for net zero emissions versus removing carbon from the atmosphere). As such, regenerative agriculture entered the field by striving to address "the land by using technologies that regenerate and revitalize the soil and the environment" (Leu, 2020, p. 27).

Despite its inception in the late 20th century, though, it wasn't until the past few decades that the practice gained momentum. Alongside collective mobilization to address climate change, regenerative agriculture gained international recognition in 2015 with the creation of

Regeneration International, a non-profit organization with over 500 partners around the globe (FAO, n.d.-a). In the last decade, regenerative agriculture has become much more prevalent as both a concept and a practice, with recent estimates of nearly 700,000 acres of regeneratively farmed land in the US (*Discover Sustainable Agriculture*, n.d.). While this represents major progress over a relatively short period, this represents roughly 1% of farmed land in the US, leaving huge opportunities for improvement and expansion. Part of the challenge of both advocating for and accounting for regenerative agriculture is the nature of the practice, which can be ambiguous and general. Developing a strong definition of regenerative agriculture is a consistent challenge for stakeholders in the field, and requires careful consideration, especially for its incorporation into US agricultural policy.

2.3.2 Defining Regenerative Agriculture

There are several reasons it is challenging to generate a universally encompassing definition for regenerative agriculture. Despite some broadly shared components, including the prioritization of soil health, improving ecological functions and ecosystem health, and being generative rather than extractive, the inherently context-dependent nature of the practice means specific definitions vary by area, scale, and stakeholder. A recent review by researchers at the University of Colorado Boulder drew attention to this issue, looking at over 250 sources to characterize regenerative agriculture:

> Our review revealed that there were many definitions and descriptions of regenerative agriculture in usage. These were variously based on processes (e.g., use of cover crops, the integration of livestock, and reducing or eliminating tillage), outcomes (e.g., to improve soil health, to sequester carbon, and to increase biodiversity), or combinations of the two (Newton et al., 2020, p. 1).

This division between process-based and outcome-based definitions has been a source of tension among proponents of regenerative agriculture and poses a challenge to making effective and actionable policy. Variability in definitions has created uncertainty and division amongst regenerative advocates and inhibits the development of certification programs and other incentives for institutionalizing regenerative practices. The authors of this review comment on this issue as well, stating "the absence of a clear understanding of what regenerative agriculture is, and whether it is or should be process- or outcome-based, has implications for policy and program development", including "how this form of food production is perceived by a variety of stakeholders, including policy-makers and consumers" (Newton et al., 2020, p. 9).

An effective definition will be discussed in more depth in Chapter 3 when discussing the integration of regenerative agriculture into policy to address the concerns posited by Newton et al. For the sake of this paper, I will use a definition maintained for the last four decades, coming from Allan Savory, a close partner of Robert Rodale, who expanded upon the ideas of regenerative organic agriculture and focused heavily on holistic management; "*Regenerative agriculture is the production of food and fiber from the biological life of the world's land and waters through managing simultaneously the indivisible complexity of human organizations, economy, and nature to sustain all businesses, economies, and civilization*" (Cummins & Leu, 2024, p. 62). A few comments on this definition; first, this definition is both process-based and outcome-based, discussing both the production of resources and the process of management. Second, it is evidently and intentionally broad– there is a huge array of practices that fall under the definition of regenerative agriculture, including organic agriculture, permaculture, and agroforestry, to name a few. Lastly, and perhaps most importantly, this definition emphasizes the human involvement and benefit of regenerative agriculture, balancing criticisms that view

regenerative agriculture as overly reductionist or regressive. In reality, this framework for producing food is in coordination with human societies and needs. Sustainable or organic agriculture that displaces Indigenous peoples is not regenerative, for example, nor are practices that are environmentally sound but economically infeasible.

2.4 An Emphasis on Sustainability

While there are benefits to regenerative agriculture that extend beyond ecosystem restoration and environmental impact (nutrition and public health, for example), within the scope of this investigation, regenerative agriculture is posited as a solution to improve the sustainability of food systems. The following chapter moves from unsustainable practices and environmental threats posed by industrial agriculture and offers as a contrast the alternative of regenerative practices as a more sustainable approach. Sustainability acts as the primary metric through which the two systems are contrasted. This is an important consideration, as while industrial agriculture is absolutely a threat to the environment and planetary health, the practices it utilizes have emerged out of goals of efficiency and productivity to maximize the availability of food at an affordable price for domestic and international consumers. While it is easy to demonize industrial agriculture for its impacts, it functions the way it does for a reason. This investigation focuses primarily on the sustainability (or lack thereof) of today's system in the context of environmental issues and threats to and from climate change. It is through this lens that regenerative agriculture is emphasized as an alternative to industrial agriculture, as it may not necessarily hold up to other criteria like maximal profitability or productivity.

Sustainability, though, is fundamental to the origin of regenerative agriculture. In establishing regenerative agriculture, the earliest proponents and creators of the practice

"stressed that to achieve sustainable food production, the resources agriculture depended upon initially needed to be restored from the degraded state conventional [industrial] agriculture had caused" (O'Donoghue et al., 2022, p. 1). Some have even argued that regenerative agriculture goes beyond the criterion of sustainability; whereas sustainable agriculture simply preserves the current state of the natural environment without damaging it for future generations, regenerative agriculture purports to improve the ecosystem. Through its emphasis on increasing soil organic matter and its dynamic and holistic approaches to food production, regenerative agriculture aims to improve and revitalize natural resources (Leu, 2020).

The importance of sustainability and environmental impact within regenerative agriculture can also be underscored by its varying definitions. In a literature review of 28 peer-reviewed publications discussing regenerative agriculture, every single source reviewed connected practices to planetary health, "mainly with improving environmental issues, which is referred to as *regenerate the system*, *reduce environmental externalities* and *improve the ecosystem*." (Schreefel et al., 2020, p. 3). The authors further identify sub-themes within the scope of improving environmental issues focusing on soil health, resource management, climate change, and water quality. Improving these areas is fundamental to regenerative practices and also contributes to the four environmental impact criteria discussed in section 2.2. Regenerative approaches offer an alternative to the "degenerative" impacts of industrial agriculture driven by maximizing yields and profit regardless of the environmental externalities.

2.5 Conclusion

Considering both the historical and present methodologies and practices of industrial agriculture, regenerative agriculture is markedly distinct, both in processes and outcomes, and

represents a potential for improvement in terms of sustainability. Examination of key environmental impact criteria including land use, greenhouse gas emissions, freshwater use, and nutrient cycles establish that the current agricultural system is in need of reform, especially in light of the ever-looming threat of climate change, which will only further compound current damages. This is highlighted by the example of the Dust Bowl, which acts as both a warning and a precedent for how degenerative and unsustainable practices can have devastating environmental, social, and economic impacts.

In contrast to industrial agriculture, regenerative agriculture acts directly to improve agricultural ecosystems, making them both more resilient to the impacts of climate change, and less problematic as contributors to climate change, even acting to sequester carbon from the atmosphere. However, careful attention is needed to define the concept of regenerative for its application, both for policymakers and food producers trying to understand the practice. In the next chapter, the scientific evidence for regenerative management and the nuances of the approach as an alternative to industrial agriculture will be addressed to highlight the necessity and considerations of building out more effective policy to directly support regenerative agriculture.

Chapter 2: The Case for Regenerative Agriculture: Scientific Evidence and Feasibility for Producers

"*A tree has roots in the soil yet reaches to the sky. It tells us that to aspire we need to be grounded and that no matter how high we go it is from our roots that we draw sustenance*"[3]

Wangari Maathai

Kenyan environmental activist and founder of the Green Belt movement

(1940-2011)

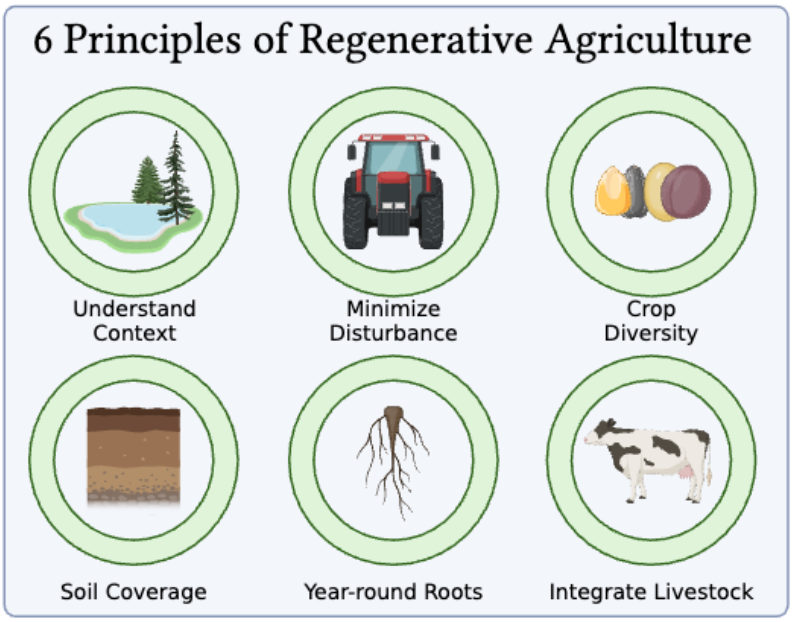


Figure 6. The six principles of regenerative agriculture, attributed by many to Gabe Brown's *Dirt to Soil* (2018), drawing on decades of practice and theory from regenerative agriculture proponents. Created by the author using BioRender.

3.1 Introduction

Industrial agriculture, while highly productive, is unsustainable and actively contributing to climate change and the continued degradation of ecosystems and landscapes across the

[3] (Maathai, 2007, p. 291)

country. Regenerative agriculture, while still representing only a small fraction of the agricultural space, offers a promising alternative to industrial agriculture, regenerating natural cycles and resources while still potentially producing sufficient output both for human consumption and for food producers' prosperity. Knowledge of the actual practices and evidence for the benefits of regenerative agriculture is critical to building a compelling case for expanding regenerative agriculture through its explicit incorporation into agricultural policy. This chapter will explore the science of regenerative practices to demonstrate their concrete improvements in sustainability over current practices, discuss the scalability of regenerative agriculture, posit economic incentives for producers to make this transition, and lastly, discuss the accessibility of regenerative agriculture across the country. As a whole, this chapter will reflect on both the promises of regenerative agriculture and the obstacles, both actual and perceived.

The content of this chapter will provide a synthesis of the evidence and case for regenerative agriculture, highlighting the state of current scientific research, economic integration, and questions of ethics and access to shifting to a new practice. Regenerative agriculture is not without its flaws and unique challenges, which will also be addressed in the latter half of this chapter, considering the nuances of the practice and building out a holistic foundation for understanding regenerative approaches. Having established this base, the following final chapter will consider both the environmental impacts of the industrial agriculture system and the evidence for the benefits of regenerative agriculture to develop suggestions for incorporating regenerative approaches into existing and proposed policies.

3.2 The Science of Regenerative Agriculture

Table 1. This table produced by Al-Kaisi and Lal offers a comparison between regenerative agriculture systems and industrial (CONVA) agriculture. The regenerative approaches highlighted in the review of this investigation included no-till, cover crops, low input, crop residue cover, and less chemical input relative to 'conventional' agriculture. Adapted from "Aligning Science and Policy of Regenerative Agriculture," by M. M. Al-Kaisi & R. Lal, 2020, *Soil Science Society of America Journal, 84*(6), pp. 1808–1820 (https://doi.org/10.1002/saj2.20162). Copyright 2020 by Wiley.

Parameter					
Yield	**Unit**	**RA**	**CONVA**	**Rel. %**	**Reference**
Corn	Mg/ha	10.4	11.39	91	Al-Kaisi et al., 2015
Soybean	Mg/ha	3.66	3.64	101	Al-Kaisi, Archontoulis, & Kwaw-Mensah, 2016
Wheat	Mg/ha	6.24	6.10	102	Acar, Celik, & Gunal, 2017; He et al., 2019
Rice	ton/ha	9.98	9.97	100	Huang et al., 2011
Profitability					
Input cost[a]					
Corn	$/ha	964	1045	92	Al-Kaisi et al., 2015
Soybean	$/ha	453	510	88	Al-Kaisi et al., 2016
Net return[b]					
Corn	$ ha^{-1}	892	997	90	Al-Kaisi et al., 2015
Soybean	$ ha^{-1}	1261	1207	105	Al-Kaisi et al., 2016
Ecosystem Service					
Soil loss/erosion	kg m^{-2} h^{-1}	0.01	2.45	0.40	Bradford & Huang, 1994
Water infiltration	cm h^{-1}	8.8	3.2	275	Bradford & Huang, 1994
Wildlife habitat	Na	Increase	Decrease	na	Wildlife Management Institute—NRCS, 1999
Biodiversity	Na	Higher	Lower	na	Carbonetto, Rascovan, Álvarez, Mentaberry, & Vázquez, 2014; Lupwayi, Lafond, Ziadi, & Grant, 2012
Soil Health Indicators					
C sequestration	Mg ha^{-1} yr^{-1}	0.3-0.5	−0.5- −0.8	na	Al-Kaisi, 2020; Puget & Lal, 2005
C footprint	kg CO_2-eq ha^{-1}	−628	488	na	He et al., 2019
SOC stocks	Mg/ha	12.33	10.38	119	He et al., 2019
MBC	µg g^{-1} soil	389	181	215	Balota, Colozzi-Filho, Andrade, & Dick, 2003
Available water	cm^3 cm^{-3}	34.2	32.5	105	Acar et al., 2017
CEC	cmol kg^{-1}	13.61	12.78	107	Balota et al., 2003
Bulk density	g cm^{-3}	1.30	1.40	97	López-Vázquez, Cadena-Zapata, Campos-Magaña, Zermeño-Gonzalez, & Mendez-Dorado, 2019
Porosity	%	51	47		López-Vázquez et al., 2019

The benefits of regenerative agriculture have been widely espoused by proponents, sometimes to the point of exaggeration, as a nature-based solution to not just the US food system, but the global climate crisis. While some of these claims are overstated, there is strong scientific evidence behind the practices involved in regenerative agriculture that contribute to addressing the climate crisis via reduced emissions and sequestration of organic carbon, but

much more significantly at an ecosystem level. At the most fundamental, this is accomplished through an emphasis on soil health as the source of nutrients and natural buffer against disturbance, but other practices also contribute to restoring natural cycles, promoting biodiversity, and stabilizing disrupted landscapes.

The last chapter focused on the environmental impacts produced by the approaches of industrial systems, setting up a contrast to regenerative agriculture. Industrial agriculture was assessed against four key environmental impact criteria and was identified as in need of improvement in environmental outcomes. Holding regenerative agriculture up to the light of these same four criteria and unpacking the scientific evidence behind this alternative approach further establishes the regenerative framework as a pathway toward a more sustainable food system. While these criteria are by no means exhaustive, they establish a clear argument in favor of shifting away from industrial approaches toward more sustainable and regenerative-driven practices.

3.2.1 Land Use

It is important to acknowledge that regenerative agriculture does not directly improve issues associated with land use; land that changes from being used for industrial to regenerative agriculture is still being fairly intensively managed for food production to serve human societies. However, the critical distinction between the two approaches against this criterion falls into the associated *impacts* of land used for agriculture. Where land used for industrial agriculture reduces and threatens biodiversity, inhibits ecosystem services, and risks reducing economic returns over time, land used for regenerative agriculture improves in all of these areas. Furthermore, in considering the looming shift in climatic conditions for present agriculture,

regeneratively managed land is more resilient and less susceptible to degradation as a result of climate change.

Looking first at impacts on biodiversity, the scientific evidence is clear on the improved impact of regenerative agriculture. Referred to by some authors as "biodiversity islands," areas under regenerative management actively strive to "[harmonize] agricultural productivity and biodiversity conservation" (Levin, 2022, p. 61) through a variety of practices that encourage a multitude of species (as opposed to a monoculture model common to large-scale industrial agriculture) such as intercropping, cover cropping, and silvopasture, or the integration of trees into grazing land for livestock and animal agriculture. They also reduce practices that can be detrimental to biodiversity such as agrochemical applications including herbicides and pesticides that penetrate food chains and threaten native species. Furthermore, through maintaining soil health and actively contributing organic materials, the biodiversity of the soil microbiome is directly improved, which in turn contributes to overall system biodiversity (FAO, n.d.-b).

Lastly, land that is managed under regenerative agriculture is much more resilient to climate change, including variability in the natural water cycle and local surface soil temperatures (Khangura et al., 2023). Furthermore, land under regenerative management has been conclusively demonstrated to release fewer greenhouse gasses and serves to directly sequester carbon dioxide from the atmosphere through some of its most fundamental practices to support soil organic matter (Prescott et al., 2021). Resiliency is critical to the future of American agriculture, as improvements to resiliency from regenerative management could reduce the need for future land use conversion as climate change shifts growing conditions regionally (recall Figure 4). Underscoring the fundamental mission of the approach, regenerative agriculture aims to actively improve the land upon which it operates, through the restoration of natural resources,

the sequestration of organic matter and carbon, and vast improvements in biodiversity over industrial approaches.

As one final critical discussion pertaining to land use under regenerative vs. industrial agriculture, the question of intensification versus extensification arises. Intensification has led to many of the environmental threats posed by industrial agriculture, serving to increase the amount of capital and input applied per unit of land. Extensification is a portion of the argument made by many regenerative advocates, to reduce the amount of input applied per unit of land, favoring differential practices attuned to natural resources to reduce the need for external inputs (Postma-Blaauw et al., 2010). However, concurrent with this reduction of inputs is the need for an expansion of land area to reduce intensity of management without also reducing productivity and yields, critically relevant for food production. The question of intensification and extensification is currently playing out across the globe as more and more attention is directed towards increasing food production across the world's increasingly limited supply or arable lands. For the US, this question becomes relevant when considering a transition to regenerative agriculture, which is much more likely to maintain outputs while reducing environmental inputs if more land is taken up under regenerative management.

At its core, this debate boils down to whether a smaller amount of land should be managed more intensively to protect other non-agricultural uses of land, or whether it is more important to manage existing agricultural lands less intensively, and allow for the expansion of agriculture into an already limited body of territory. There is no clear objective answer to this question; both sides have benefits and consequences for environmental impacts. Focusing primarily on the goal of sustainability, regenerative advocates would argue that increasing land for regenerative management should be encouraged, as this land also holds value for

conservation, biodiversity, and carbon sequestration, among other ecosystem services, although recovery rates could be on the timescale of decades (Horrocks et al., 2014). Critics would argue that as populations grow, agriculture should become more concentrated to reduce the total net area used for agricultural production. It is unclear whether intensification and regenerative management approaches can co-exist, and this is certain to remain a critical point of inquiry for addressing the sustainability of the American food system.

3.2.2 Greenhouse Gas Emissions

Greenhouse gas emissions from agriculture have been both the subject of scrutiny and an area demanding immediate attention to improve climate change contributions for over a decade. In a 2010 report from the USDA, agriculture was identified as a potential route for reducing national greenhouse gas contributions through various techniques utilized in regenerative practices, including land management, tree planting (agroforestry), conservation tillage, and reduced application of nitrogen fertilizers (Horowitz & Gottlieb, 2010). Regenerative agriculture as a whole has been demonstrated to directly contribute to reduced net greenhouse gas emissions compared to industrial agriculture. The United Nations Environmental Programs identified in 2015 that different regenerative practices, especially no-till, have contributed to reduced emissions of 241 Tg [teragrams] of carbon dioxide since the 1970s (Al-Kaisi & Lal, 2020). For reference, this is a little less than half of the net annual greenhouse gas emissions in the US, which has remained fairly constant in the last five years at around 600 Tg of carbon dioxide equivalent (EPA, 2024). This demonstrates both the potential of regenerative agriculture as a mitigation strategy for reducing US contributions to greenhouse gas emissions and climate change and the urgent need to reduce the present impacts of industrial agriculture.

In a recent review of the evidence and science supporting the climate and environmental benefits of regenerative agriculture, researchers identified that under a variety of regenerative agriculture practices, "the overall SOC [soil organic carbon] rate with all practices ranges from 0.923–8.388 Mg C/ha/year" (Rehberger et al., 2023, p. 9). This is significant firstly in contrast to industrial agriculture practices which have a negative value, removing organic matter from soils and secondly, because this sums to a significant change. There are over 160 million hectares of agricultural land in the US (U.S. Geological Survey, n.d.), thus if even 10% of that land was converted to regenerative agriculture, soil organic carbon could increase by 14.8–134.2 Tg C/year, representing roughly a quarter of the current annual GHG emissions from agriculture. The carbon sequestration potential of all systems under regenerative agriculture is not equal, though, and it is important to acknowledge when approaching a regenerative transition that the most impactful reductions in emissions will come from targeting land that has been the most intensively managed and holds the highest potential for carbon storage (Rehberger et al., 2023).

3.2.3 Freshwater Use

One of the most explicit and noticeable differences between regenerative agriculture and other agricultural practices is the ability of soils to retain water. As discussed in Chapter 1 and the case study of the Dust Bowl, industrial agriculture tends to produce soils that are depleted of structure and nutrients and that are highly susceptible to erosion. Consistent tillage and application of various "biocides" destroy organic matter and root networks in the soil, driving the need for chemical fertilizers and increased irrigation and watering as degraded soils lose the ability to retain moisture, resulting in significant runoff (Mulvihill, 2021).

Regenerative agriculture, through its avoidance of disturbance and minimized use of mechanized tools to manage soils, does not have this same impact on the soil. Instead,

regenerative practices bolster soil's rich matrix of organic matter, making it more robust and behaving like a sponge to retain moisture, reducing the volume of water needed to promote crop growth. Improvements in soil organic matter are directly related to increased water retention, with research suggesting that each one percent increase in organic matter results in 25,000 gallons of soil water available per acre (Climate Hubs, n.d.). As water retention of soil improves, the demand for water for crops and agriculture decreases. This is especially relevant to regions like California, where water shortages are already a pressing concern, and are expected to become more so in the face of climate change and regional warming. According to California's 4th Climate Change Assessment, increasing soil organic matter by 1% across the 26 million cultivated acres within the state could reduce the climatic water deficit by 208,000 acre-feet/year, and with a more ambitious 3% this value could be reduced further by 584,000 acre-feet/year (Flint et al., 2018).

Once again, the impacts of regenerative agriculture on freshwater use will vary by region and climatic conditions. The prevalence of irrigation infrastructure, dependence on natural precipitation patterns, and water demand of different crops dictate specific and distinct contexts with different factors relevant to freshwater use. Broadly speaking, though, a regenerative approach strives to improvise soils and thus directly reduces water demand by reducing losses and runoff, lessening the environmental impact of food production and agriculture in the US.

3.2.4 Nutrient Cycling

Finally, regenerative agriculture perhaps most explicitly exhibits a reduced environmental impact compared to industrial agriculture in terms of nutrient cycling. Fundamentally, regenerative practices significantly reduce or entirely remove chemical fertilizers from their landscapes. Through a variety of practices, including intercropping and crop rotation,

regenerative agriculture makes use of natural nitrogen-fixing crops like legumes, as well as inputs like manure and compost in place of chemical fertilizers. In addition, the reduced disturbance of soils through practices like no-till maintains nutrients in soils rather than depleting them or losing them to runoff, as is the case in industrial agriculture. Once again, context matters; different regions and soils are differently limited by various minerals and nutrients, so the complete avoidance of chemical fertilizers may not be realistic. However, by reducing the input of synthetic nutrients to agrisystems, regenerative agriculture contributes to the restoration and maintenance of natural nutrient cycles, reducing the need for fertilizers and thus the negative impacts of runoff and synthetic fertilizers overall discussed in the previous chapter.

Additionally, while the primary impacts of reducing fertilizer may appear to be via improvements to natural nutrient cycles and reductions in runoff and eutrophication, there are additional benefits from decreasing the dependence on chemical fertilizers, especially in GHG emissions. The synthesis of nitrogenous fertilizers is incredibly energy-intensive, currently supplied by significant amounts of fossil fuels. Furthermore, in the production of these fertilizers nitrous oxide is produced, a prominent greenhouse gas with an outstated impact, more so than carbon dioxide (Simon, 2024). According to a 2022 study from Nature, "the synthetic N fertiliser supply chain was responsible for estimated emissions of 1.13 $GtCO_2e$ in 2018, representing 10.6% of agricultural emissions and 2.1% of global GHG emissions" (Menegat et al., 2022, p. 1). Regenerative agriculture thus has direct and indirect benefits by reducing the need for chemical fertilizers, contributing both to improved water quality and nutrient cycling, and addressing a frequently overlooked but high impact contributor to greenhouse gas emissions. By taking more regenerative approaches to improving soil fertility and nutrient availability, there is an array of ecosystem benefits produced as well as mitigation of a major source of global emissions.

3.3 Regenerative Agriculture Practices

In discussing the scientific evidence behind how regenerative agriculture reduces the environmental impact of agriculture and food production, several techniques have been mentioned. These practices are diverse and differ based on the landscape and broader context of each operation, but maintain many similarities that support the overall mission of managing "the indivisible complexity of human organizations, economy, and nature to sustain all businesses, economies, and civilization" (Cummins & Leu, 2024, p. 62) as defined in the previous chapter. There exists a wide breadth of sources and publications that provide detailed reviews of the various practices and techniques involved in regenerative practices. Rather than discuss each at length, some of the most common and impactful are discussed here, as well as the commonly recognized six key principles of regenerative agriculture shown in Figure 6 that transcend specific practices.

No-till is one of the most common and fundamental practices employed in regenerative agriculture, as well as one of the most self-explanatory. No-till practices exist in opposition to the conventions of industrial agriculture of industrial tillage, which was originally applied as a method of suppressing weeds and aerating soils (Environmental Conservation CRP, 2020), but now results in the destruction and degeneration of healthy soils. Importantly, tillage was one of the first major innovations in the earliest form of agriculture, acting as an extremely effective method of suppressing weeds, increasing productivity and decreasing labor needed for food production. Despite this, increased disturbance of soils has a series of environmental impacts, beginning with the destruction of fungal hyphae, or networks of connections between decomposing organisms in the soil that form mutually beneficial symbioses with the fine root matter of plants (Khangura et al., 2023). By uprooting and mechanically disrupting these

networks, soils become less cohesive, biological activity is decreased, and these symbiotic relationships are damaged, limiting the ability of crops to take up nutrients in the soil. The presence of nutrients in the first place is also depressed by tillage, directly limiting nutrient cycling. Furthermore, disturbed soils contribute to greenhouse gas emissions from agriculture by releasing trapped CO_2 gas into the atmosphere, and overall reduce the storage of carbon in the soil as organic matter (Khangura et al., 2023).

No-till practices thus preserve nutrient cycles and reduce carbon emissions, improve the integrity of soils, making them better able to retain carbon, nutrients, and water, and directly regenerate depleted natural resources. They may create a larger risk for weeds, but when combined with other regenerative practices like intercropping and rotational planting, the need for tillage is offset by other benefits. Furthermore, tillage, as with all regenerative alternatives, is not an all-or-nothing decision. There are degrees of no-till which can be implemented to achieve both the weed suppression benefits of tillage while still maintaining hyphal networks and carbon sequestration. A number of tools have been developed as no-till has become much more common as a less invasive method of food production, including strip-till units which only a till a narrow area for seeds to be planted, cover crop seeders which contribute to weed suppression, and coulters which can cut through soils before planting without turning it over entirely (Agrimachinery, 2024).

Intercropping is also one of the most common strategies used in regenerative agriculture to promote healthy environmental outcomes and regenerate natural resources. This practice emerged as a contrast to the large-scale monoculture practices of US industrial agriculture, notably of corn and soy. Rather than limiting a field or cultivated area to the one specific crop being raised and sold, intercropping promotes the integration of multiple crops, either directly

integrated (sometimes referred to as polyculture, mixed, or multiple cropping), or in between rows to confer different benefits (Brooker et al., 2015). This supports a diversity of crops, which draw on different resources, have different impacts on the soil, and can promote different ecosystem benefits, including the promotion of biodiversity. Intercropping can thus improve outcomes in terms of soil health, nutrient availability, and biodiversity over any number of crops grown in isolation.

Lastly, agroforestry (or the similar practice of silvopasture) is a form of regenerative agriculture that encourages actors and producers with different focuses to maintain tree species on agricultural lands. Put most simply, agroforestry is "the intentional integration of trees and shrubs into crop and animal production to create environmental, economic, and social benefits" (USDA Agroforestry Strategic Framework, 2019). In contrast to clear-cutting techniques or large-scale deforestation, agroforestry allows for remnants of existing forest plants or the intentional incorporation of tree and woody species into agricultural production. This confers an array of benefits beyond simply reduced deforestation. The maintenance of these species contributes directly to soil integrity by maintaining deep root structures and can provide habitats and resources for native species, sustaining local biodiversity. Economically, the incorporation of tree species can "boost the net value of production through the diversification of crops and other farm outputs (e.g., fuelwood), and the increase of the production area above and below ground" (Gao et al., 2014, p. 302). Further benefits from the use of tree and shrub species may be derived from their roles in acting as buffers for wind and flooding, maintaining the integrity of riverbanks, acting as natural boundaries, and offering a variety of forage for livestock like goats and sheep (Gao et al., 2014).

These examples are some of the most prominent strategies used in regenerative agriculture, but in practice, the approach is better defined by the six key principles displayed in Figure 6 rather than any particular practice. This is largely due to one of the principles, which emphasizes the importance of understanding local contexts and making decisions about the land and ecosystem based on specific conditions, including the environmental/ecological, financial, meteorological, and personal goals of producers. By acknowledging the distinct context of any given area of agriculture, regenerative approaches strive to improve upon industrial practices by responding to and building upon the natural environment and resources rather than imposing foreign practices and conditions onto them. Producing with, rather than from, the land contributes to the improved environmental impact of regenerative agriculture and its overall sustainability. The remaining principles can be exhibited by the sample of practices discussed above; for example, no-till minimizes disturbance and promotes year-round roots. Intercropping contributes to crop diversity and the maintenance of soil coverage. Agroforestry does the same, and can also support the integration of livestock by offering feed to grazers and browser herbivores. In striving to meet these six key principles, the goals of regenerative agriculture can theoretically be achieved within and directly in response to the needs of any given context.

3.4 Scalability of Regenerative Agriculture

At this point, the case for regenerative agriculture may seem ironclad; the science supports a significantly improved impact on the environment, profits may be comparable if not higher than industrial agriculture, and the indirect benefits provided through various ecosystem services have effects that extend beyond the scope of food production. However, regenerative agriculture is not the holy grail to all of the inefficiencies and externalities of industrial

agriculture, and several barriers exist at each stage of the transition to regenerative agriculture that can limit its efficacy as a solution to improving the sustainability of the US food system.

One prominent challenge of transitioning to regenerative agriculture is scalability, with a majority of land currently under regenerative management being limited to small- and medium-sized producers (Kinsky, 2024). Additionally, the economic and political barriers to making this change can limit the ability of producers to reduce their environmental impact. Finally, there is a lingering question of accessibility to regenerative agriculture. As mentioned in the Introduction, many of the practices proselytized by regenerative agriculture proponents are directly drawn from traditional Indigenous practices. Many critics of regenerative approaches to agriculture have accurately highlighted the shadow of cultural appropriation latent to its emergence as a solution, as a movement that "excludes BIPOC farmers and disregards their longtime contributions to sustainable farming" (Mishler, 2023, para. 6). These are legitimate and important challenges facing regenerative agriculture, and will each be discussed in the following sections, beginning with the question of scalability.

Scaling up of regenerative agriculture has been simultaneously demanded and problematized since the conception of the approach as an alternative to industrial agriculture practices. According to a white paper produced by the Sustainable Markets Initiative Agribusiness Task Force, "regenerative farming needs to scale three times faster to address the threat to a resilient sustainable food supply presented by climate change and biodiversity loss" (The Sustainable Markets Initiative, 2022, p. 5). The task force's white paper (2022) proceeds to identify three major barriers to this goal; short-term economic losses deterring farmers from transitioning their operations, a lack of knowledge on how to effectively implement regenerative agriculture, and a lack of drivers in the value chain to incentivize a shift among producers. These

obstacles are significant, and oftentimes prohibitive for farmers that may otherwise have interest in transitioning to a regenerative approach. Issues like these beg the overarching question of whether regenerative agriculture can compete with the large scale of many current operations.

Fortunately, this may not be as much of an issue as it may seem. Despite the challenges for small farmers, data from the USDA demonstrates that small-scale family farms make up a striking proportion of US farms:

> Small family farms, those farms with a GCFI [gross cash farm income] of less than $350,000 per year, account for 88% of all U.S. farms, 46% of total land in farms, and 19% of the value of all agricultural products sold. Large-scale family farms (GCFI of $1 million or more) make up less than 3% of all U.S. farms but produce 43% of the value of all agricultural products. Mid-size farms (GCFI between $350,000 and $999,999) are 5% of U.S. farms and produce 20% of the value of all agricultural products (Nseir & White, 2021, para. 4).

There is still clear competition; despite composing a majority of U.S. farms, small family farms are still underperforming mid- and large-scale operations both in value and land area. However, as the following chapter will demonstrate, the barriers to transitioning to regenerative agriculture can be reduced, allowing for a scaling up to meet the identified urgent needs. This issue also begs the question of the most effective scale for agriculture in the US. While this question extends beyond the scope of this investigation, some proponents of more sustainable agriculture advocate for a scaling down of farm sizes and an emphasis on more localized supply chains. This question will be touched on in the Conclusion of this paper, but the nuance of reducing farm sizes requires further research and economic analysis to understand the feasibility of systemically shifting away from large-scale production.

3.5 Economic Incentives for a Regenerative Transition

There is no clear consensus on the economic practicality of regenerative agriculture. For one, profitability is highly dependent on the different regenerative practices employed, the crops produced, their market value, and the economic, political, and geographic context surrounding potentially regenerative producers. Furthermore, while proponents defend increases in profits from net returns when considering potential increases in yields and decreases in input costs, margins compared to industrial agriculture are slim, as can be seen in comparing corn and soybean under regenerative agriculture vs. "conventional agriculture" in Table 1. Regenerative approaches are estimated at a net return that is only 90% that of industrial agriculture for corn but are estimated at an increase of 105% for soybean (Al-Kaisi & Lal, 2020). Narrow margins like these, combined with the inherent risk associated with agriculture due to unpredictable climate and weather conditions, especially in the face of increasing variability from climate change, suggest that food producers are not presently as economically motivated to transition as they could be.

Furthermore, the timeline across which transitioning to regenerative agriculture can occur is somewhat gradual. Making a significant change to production involves shouldering a somewhat steep initial cost, already beyond the margins of profit for many farms. As demonstrated in Figure 7, farms that make a change to adopt regenerative techniques take several years to recover their breakeven profits per hectare. With added risks of natural climatic variability, disease and pest outbreaks, and crop failures, this can be a major discouraging factor preventing food producers from adopting more regenerative practices.

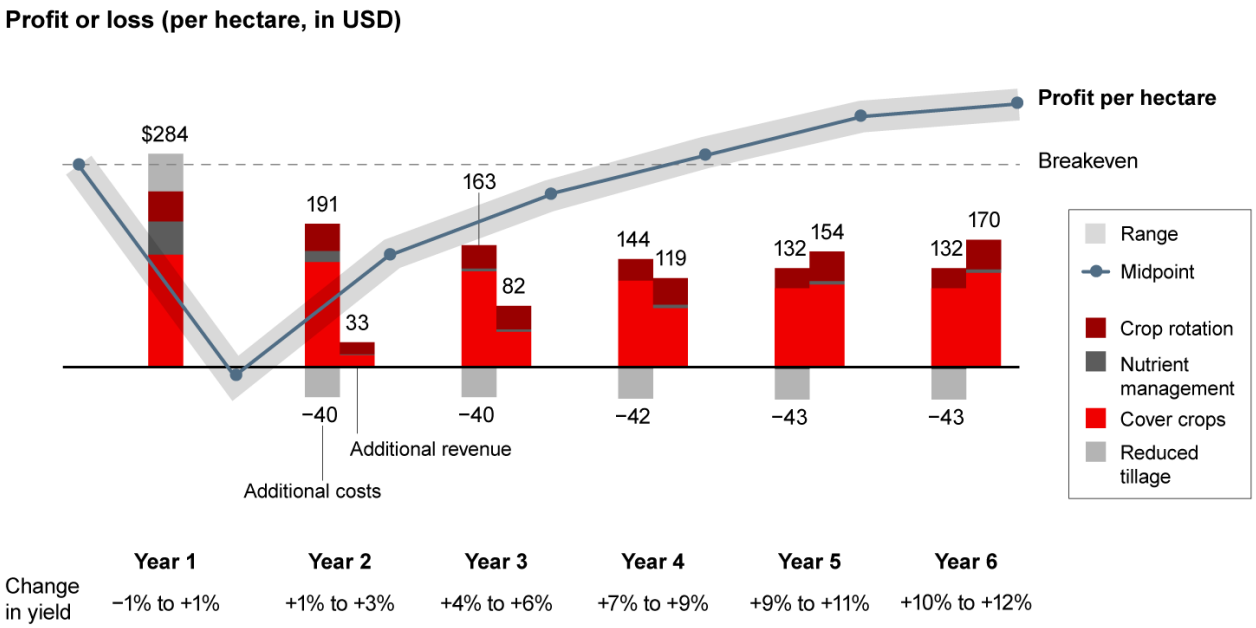


Figure 7. Bain and Company estimates that it takes at least four years for the average farm to recover baseline profits when transitioning to regenerative techniques. Adapted from "Helping Farmers Shift to Regenerative Agriculture," by F. H. Lutiis, T. Atleo, G. Mzabima, & S. Israelit, 2021, *Bain & Company* (https://www.bain.com/insights/helping-farmers-shift-to-regenerative-agriculture/). Copyright 2021 by Bain & Company.

Additionally, a large part of the difference between industrial and regenerative management of agricultural land is not captured economically due to a failure to both exact costs for environmental impacts and recognize the economic value of improving ecosystems and natural cycles. To the former point, industrial agriculture is rife with externalities, or costs of food production that are not borne by the food producers but rather collectively, on scales from local to regional. This is true for all of the environmental impact criteria used to evaluate regenerative agriculture versus industrial agriculture in this and the previous chapter. For example, nutrient cycling has significant impacts on water quality, the costs of which are frequently borne by citizens or water utilities. In an economic assessment conducted by Dodds et al. (2008), the authors estimated the costs of eutrophication of rivers and lakes in the US to be approximately $2.2 billion annually, calculated across "losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and drinking

water" (12). Similar avoided costs occur for greenhouse gas emissions and land use, where the loss of ecosystem services is not included within the existing market structure of US agriculture. Introducing an economic tool that shifts this externality cost onto industrial farmers could help support adoption of regenerative practices by making them more economically competitive. The following chapter considers these externalities and discusses policy solutions to help better reflect the costs and benefits of different agricultural processes to shift the balance of profitability toward more sustainable approaches like regenerative agriculture.

As far as the lack of recognition for the economic benefits conferred by transitioning to regenerative agriculture, there is some promise, but still significant room for improvement. The most obvious example of this is the growing area of carbon credits and carbon markets. Carbon markets are not new and have been discussed in the context of agriculture for decades as a way of incentivizing carbon sequestration and mitigating greenhouse gas emissions. In 2003, agriculture was just emerging as a new sector into carbon sequestration, where out of the total 369 US sequestration projects at the time, just 2 involved agriculture compared to 362 in forestry (Young, 2003). This was largely due to a lack of robust policy and infrastructure supporting carbon markets. Today, there is much more significant awareness and attention to the economic value of carbon sequestration in agriculture, specifically "credits generated from atmospheric drawdown of carbon dioxide (CO_2) with sequestration in the soil through management changes in arable systems" (Oldfield et al., 2022, p. 1222). There has also been growth in global carbon markets, bolstered both by US policy like the Growing Climate Solutions Act and technical guidance produced by the EU for successful sequestration of carbon through farming (Oldfield et al., 2022).

With growing interest and economic markets for carbon credits, and an increased focus on internalizing environmental costs from industrial agriculture, regenerative agriculture has the potential to become increasingly profitable. For example, the Growing Climate Solutions Act, passed in 2021, has established a way for "producers to generate and sell carbon credits by setting up a third-party certification process through the U.S. Department of Agriculture" (The US Senate Committee, 2021), and represents landmark progress as well as a critical foundation for providing economic incentives for sustainable agriculture. However, this is dependent on sustained attention to the economic value of natural resources and economic services, as well as successful monitoring and reporting of improvements by regenerative producers. The final chapter will develop potential political and economic solutions to driving this change but barring significant progress, regenerative agriculture risks slow adoption or remaining a fringe framework due to economic and financial barriers.

3.6 Accessibility: Which Producers Can Be Regenerative?

Before building out the strategies for incorporating regenerative agriculture into US policy, careful attention must be given to accessibility, as inequity is a characteristic problem within the large-scale modern US agricultural system. For example, regenerative agriculture was embraced by major global food companies just two years ago as part of a "Sustainable Markets Initiative Agribusiness Task Force," backed by major parties like Bayer, PepsiCo, Mondelez International, and McDonald's, but also smaller proponents of sustainable agriculture like Indigo Ag (*Sustainable Markets Initiative*, 2023). This consortium holds promise but should also be approached with caution; the investment of major corporations is sure to facilitate regenerative agriculture becoming more mainstream, but it also ties the term heavily to industrial agriculture

and risks the practice being written off as a form of greenwashing. This concern will be addressed at more length in discussing the role of the private sector in a regenerative transition in the following chapter. It is easy for major corporations to experiment with regenerative agriculture while maintaining significant investment in industrial approaches, simultaneously using the term as a way of appealing to consumers and appearing more eco-friendly. The challenge of accessibility lies in making sure that small-scale farmers are also able to make this transition, including those from historically disadvantaged groups which tend to have smaller holdings (Collins et al., 2024).

The ability of smaller producers to enter into regenerative agriculture is largely a question of context, specifically ecological, economic, and political contexts. To the point of ecological context, some lands are simply more fertile and better suited to food production than others. Similarly, some parts of the country are more prone to drought and climatic variability than others, or exist in proximity to major population centers of dense industrial or residential land use, resulting in pollution, runoff, and other local impacts. It is both unjust and inaccurate to argue that anyone can become a regenerative farmer wherever they are; part of regenerative agriculture is understanding the local environment, and being able to recognize when food production is simply not part of the equation for regeneration and effective restoration of the land. Regenerative agriculture is thus limited in accessibility by these ecological and geographical factors.

More glaringly, though, are the economic and political barriers that simultaneously support industrial agriculture and inhibit a regenerative transition. As was shown briefly in the case study of the Dust Bowl, the government is eager to step in to ensure the successful maintenance of high yields, which in turn requires promising profit margins to farmers willing to

generate large volumes of staple crops like corn and wheat. These frequently take the form of subsidies, including crop insurance, subsidized crops, and farm subsidy programs that favor larger and wealthier producers. Crop insurance is offered through the Farm Bill, a series of agricultural policies updated every five years which will be discussed at length in the following section. The stated goal of this bill is "to provide farmers some degree of protection against unpredictable disasters or sudden price declines" (Hackett, 2023b, para. 2) but in reality, this protection is frequently afforded to large-scale producers rather than the small-scale farmers in need of support. Crop insurance is available through the Federal Crop Insurance Program (FCIP), a public-private partnership that subsidizes the costs for farmers to purchase insurance policies from private-sector insurers. Farmers must file claims over insurable commodities, at the discretion of the insurance producers to award payment based on "the projected value of a farmer's product" (Hackett, 2023a, para. 7). This already steers farmers toward commodity crops with well-established insurance product values. It also limits the level of risk farmers are willing to take toward a regenerative approach for concerns over not receiving support in the form of crop insurance.

Even more directly, further stipulations for insurance dictate that "farmers must adhere to 'Good Farming Practices' as defined by RMA [Risk Management Agency] to qualify for indemnity payments in the aftermath of an insurable event. RMA currently maintains that a practice that reduces yields may not be considered a Good Farming Practice" (Hackett, 2023, para. 9). Regenerative approaches frequently resulted in temporary yield reductions, thus creating a barrier to transitioning, especially for small farmers. As a result, according to a report using data from the National Agricultural Resource Management Survey, "Crop insurance subsidies are consistently heavily concentrated on the largest farms. The largest 10 percent of

farms receive 56.4 percent, and the largest 5 percent receive 36.4 percent, of all crop insurance subsidies" (Belasco & Smith, 2022, para.1). In other words, these crop insurance subsidies, designed to help keep farmers afloat, have left small producers to struggle while large farms remain comfortable.

Crop subsidies themselves further exacerbate this reliance on industrial agriculture-style approaches. These are less complicated than crop insurance programs, but tend to have similar impacts; "The most highly subsidized crops—corn, soy, wheat, and rice—are the most abundantly produced and most consumed" (O'Neill Hayes, 2021, para. 2). At a glance, this may seem intuitive, but it effectively inhibits diversity in both producers and the market. Small-scale farmers are less likely to receive subsidies for fruit and vegetable crops, or other agricultural outputs outside of these highly produced commodity crops. However, due to the prevalence of large producers and monocultures, smaller farms are also unlikely to be able to compete with larger producers already growing these subsidized crops in such large quantities, leaving little room to break in and forcing small-scale producers to remain on the margins. For regenerative agriculture, which encourages multiple crops, and crop rotation, and focuses on regenerating natural resources rather than maximizing yields, this is a major barrier for historically disadvantaged groups.

Examinations of farm subsidies as a whole confirm the trend of favoring larger producers. A recent survey by the Environmental Working Group plainly reveals the deeply embedded flaws of current policies:

> The top recipients are large and wealthy farms because that's how farm subsidy programs are designed – payments are made based on acreage or production, so the farms with the most acres or most crops produced get the largest payments. Meanwhile, the smallest 80

> percent of recipients – those that, by virtue of the small size of their operations, only qualify for small payments – collectively received only about 9 percent of subsidies (Schechinger & Faber, 2023, p. 8).

To answer the titular question of this section, regenerative agriculture is not accessible under the current political and economic framework of the US food system. Some have been able to enter into a financially viable model for regenerative production through alternative forms of support, including investors, carbon credits, and nonprofits. However, if regenerative agriculture is to be the solution its proponents promise, it must rapidly be made significantly more accessible.

3.7 Conclusion

This chapter has laid out the case for regenerative agriculture; more nuanced than the universal climate solution some proponents insist it is, and more economically feasible than some of its critics claim. Ecologically, it is beyond a doubt a solution to many of the downfalls of industrial agriculture in the US, as demonstrated by holding it against the same environmental criteria. The economic realities are less promising, although margins of difference are slim, and there is significant potential for higher profitability under an economic regime that gives more attention to externalities and "true costs." For producers with a sufficient safety net to fall back on during a transitory period, it appears likely that adopting regenerative practices will be beneficial, especially in terms of sustainability. However, this is not the reality for most producers.

The question of accessibility undermines much of the benefits of regenerative agriculture, an unfortunate reality given its scientifically demonstrated improvements relative to industrial

agriculture, especially in terms of environmental impact. Despite well-understood and environmentally sound practices, regenerative agriculture is not at present a realistic choice for many producers in the US. Change may still come from larger producers, as demonstrated by the consortium including PepsiCo and Mondelez International, but this is likely to be much more gradual, and to be truly effective requires a systemic overhaul of existing practices. The problem, and the solution, lie in improving US agricultural policy. Incorporating economic incentives, reimagining federal subsidy programs, and explicitly considering environmental impacts and ecosystem services all need to be embedded into policy frameworks and enforced to make this transition possible. The following chapter discusses some potentially promising proposals for doing so and lays out the groundwork of a plan for entering into the next Agricultural Revolution.

Chapter 3: The Road to Revolution: Policy Suggestions to Facilitate Transitioning to Regenerative Agriculture

"*The care of the Earth is our most ancient and most worthy, and after all our most pleasing responsibility. To cherish what remains of it, and to foster its renewal, is our only legitimate hope*"[4]

Wendell Berry

American farmer, author, poet, and early proponent of sustainable agricultural practices

(1934-)

4.1 Introduction

Given all that has been established regarding regenerative agriculture, it is clear that this practice can act as a critical part of the urgently needed sustainable reform of the US food system. Current agriculture policy provides some potential inroads for implementing regenerative approaches, but presently tends to favor large-scale, monoculture style industrial agriculture. As long as US policy continues to make this model profitable for producers, there will be a barrier to transitioning. However, this model is characterized by negative environmental impacts, externalities, and inequities. Regenerative agriculture offers an alternative that is ecologically sound, contributes to combatting the climate crisis, and can be economically viable. Industrial practices have managed to remain the rule rather than the exception due to a complex network of subsidies, policies, and disregard for costs borne by others.

[4] (Berry, 2018)

This problem extends throughout the history of American agriculture, as introduced in Chapter 1 with the case study of the Dust Bowl. When the US government found itself in the midst of a severe environmental and economic crisis, rather than assessing and altering the methods of food production, it created policy solutions to bail out farmers, like the Wheat Stabilization Act of 1919. This trend has continued through the modern day, with each new piece of legislation building on those that have come before, entrenching the modern agricultural landscape in a complex web of dependencies and putting tight constraints on food producers to maintain the status quo. As discussed previously, the Dust Bowl offers an example and analog to today's climate crisis, with increasing climatic variability, trends of drought and erosion, and an urgent need to reduce greenhouse gas emissions without compromising the economy and livelihoods of food producers. Understanding this complex web and how it informs current agricultural practices allows for a critical examination followed by a series of proposals for improving US policy at multiple scales to open the door for regenerative approaches and correct the course of the American agricultural system. With the Farm Bill extended for the second year in a row (Held, 2025), the time to make these changes is ripe, and their implementation could turn the US into a leader in sustainable agriculture, laying out a path for other nations to transform the global food system.

4.2 Major Existing Agricultural Legislation

4.2.1 The Farm Bill

The Farm Bill is the most important and broadly encompassing piece of agricultural legislation in the US. First established in 1933 as part of the New Deal and in response to the economic and ecological factors driving the Great Depression and the Dust Bowl, the

Agricultural Adjustment Act of 1933 (the first installment of the Farm bill) established a series of subsidy programs to control prices of certain commodity crops (World Food Program USA, 2023). Since its creation, the bill "governs an array of agricultural and food programs" and "provides an opportunity for policymakers to comprehensively and periodically address agricultural and food issues" (Monke & Johnson, 2024, para. 1), revisited on a five year basis. For the first few decades, this bill was dedicated solely to maintaining crop prices for a number of key crops, including corn, wheat, and soybeans. However, since 1973 the scope of the bill has increased, when a nutrition title was introduced. Over time, the bill has continued to expand to touch on nearly every sphere of food and agriculture in the US, including conservation, research, bioenergy, and horticulture.

The bulk of this funding designated by this bill is not spent on agriculture or food production at all, but actually supports the Supplemental Nutrition Assistance Program (SNAP), which "provides food benefits to low-income families to supplement their grocery budget so they can afford the nutritious food essential to health and well-being" (USDA, 2024, para. 1). This program, commonly referred to as food stamps, is essential for ensuring food access to millions of families in the US and, as demonstrated in Figure 8, represents nearly 80% of the 2018 Farm Bill's spending, a sum of $326 billion. This leaves a total of $98 billion over five years for the remaining titles, which include crop insurance, commodities, and conservation efforts. In other words, herein lies the body of funds that could serve to support regenerative efforts by food producers.

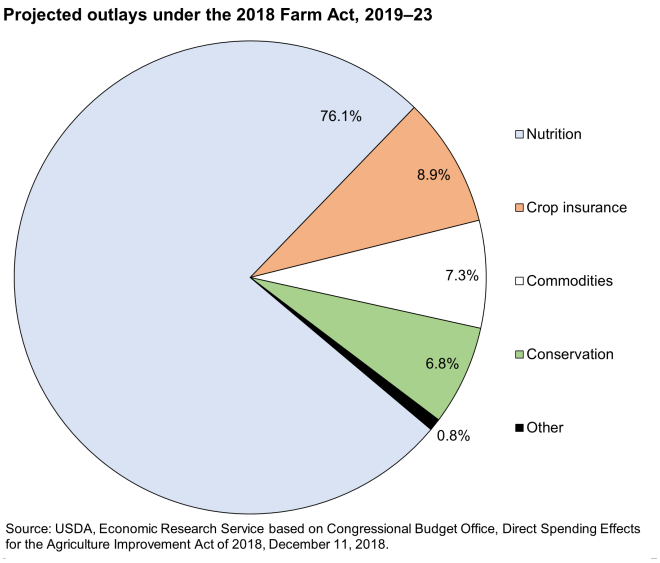


Figure 8. A breakdown of the spending allocated under the most recent 2018 Farm Act, with the vast majority (76.1%) being directed to spending on nutrition. Reprinted from "Farm Bill Spending," by *U.S. Department of Agriculture, Economic Research Service*, 2024 (https://www.ers.usda.gov/topics/farm-economy/farm-commodity-policy/farm-bill-spending/). In the public domain.

Independent of the spending on nutrition, which is critical for ensuring access to healthy foods for over 40 million Americans across the US (DeSilver, 2023), this budget is already criticized as insufficient for supporting food producers in the nation, especially considering the inequitable distribution of subsidies promised by the bill, let alone to allow for the adoption of regenerative approaches. Firstly, as discussed in the last chapter, subsidies are poured into the largest farms based on their acreage and ability to turn out significant volumes of commodity crops, especially corn and soy. Additionally, recent iterations of the bill have put increasing emphasis on Title III: Trade, increasing the presence of US crops and exports in foreign markets (Agricultural Improvement Act, 2024). Aside from the increased impact on climate produced from the carbon footprint and GHG emissions associated with international transportation of food products, this also disadvantages smaller producers who must either band together in coalitions, sell to a distributor, or limit themselves to local sales of their products. Furthermore,

the bill has done little to address the sprawl of "Big Agribusiness," as stated succinctly by a special report to Family Farm Action Alliance:

> Agrifood consolidation reduces farmer autonomy and redistributes costs and benefits across the food chain, squeezing farmer incomes. In 2018, farmers whose primary occupation was farming but with sales of less than $350,000 had a median net income of -$1,524. An agriculture system without people has depopulated rural communities causing a collapse in social relationships. Communities of color bear a disproportionate burden of exposure to excessive pesticide use or large animal confinement operations (Hendrickson et al., 2020, p. i).

The lack of action by the Farm Bill to provide farmers a degree of protection is thus manifested as an inequitable distribution of funds and a perpetuation of injustice borne by low-income, rural, and communities of color. As of 2025, the bill has been extended not once, but twice since it was due for review and revision, meaning the current policies were first drafted in 2017. In the time since, a global pandemic has disrupted global supply chains, the presidential office has changed hands and been returned, and the climate crisis has continued to rapidly impact communities and food production across the country. The next iteration of the bill will thus in some ways dictate the future of the American food system; while the country stands at a point of political divide, the climate crisis begins to impact more and more of the nation, and even still the global population grows and demands more food, the next five years of legislation could mark a significant turning point toward either a more sustainable and equitable future, or the collapse of the small farmer and monopolization of agriculture by corporations and large-scale producers.

4.2.2 Other Major Agricultural Legislation

While the Farm Bill is the most prominent route to reforming agricultural policy due to both its scope and the established precedent of altering the political landscape for food producers on a regular basis, there are other major pieces of agricultural legislation that are relevant to understanding the state of both the current and future food system. For example, the Soil Conservation and Domestic Allotment Act was established in 1936, in response to both the Dust Bowl and the hasty policy solutions like the first iteration of the Farm Bill, the Agricultural Adjustment Act (Soil Conservation and Domestic Allotment, 1936). This first iteration was deemed unconstitutional by the Supreme Court at that time, and to remedy this, the Soil Conservation and Domestic Allotment Act was put in place as an explicit federal effort to reduce production through subsidies to instead encourage soil conservation and "evade the dual threats of soil erosion and agricultural overproduction" (*Soil Conservation and Domestic Allotment Act*, 2024, para. 1). Alongside the second iteration of the Farm Bill, the Agricultural Adjustment Act of 1938, this was perhaps the first precedent for federal intervention to promote sustainable practices in agriculture at the risk of decreased profits for producers. This serves as an example of not just the ability, but the understood responsibility of the federal government to simultaneously protect food producers and the sustainable use of the natural resources on which they depend.

In addition to the Soil Conservation and Domestic Allotment Act and the series of Farm Bills, the Agricultural Act of 1949 acts as a "permanent law" for agricultural subsidies in the event the Farm Bill is not reauthorized. This act pares down the several titles encoded within the Farm Bill and serves most simply "To stabilize prices of agricultural commodities" (Agricultural Act of 1949, 1949, p. 1051). Stripped of the nutrition, conservation, and other titles, this piece of

legislation serves to preserve profitable yields of a small number of commodity crops, including tobacco, corn, wheat, and rice, among other products like wool, cotton, and dairy products. In the unlikely event that the Farm Bill is not reauthorized, this outdated piece of legislation would leave food producers dependent on the numerous other programs supported by the Farm Bill stranded. That this remains the default demonstrates the extent to which modern agricultural policy is out of touch with the needs of today, especially in terms of sustainability.

4.2.3 Programs Established by the Farm Bill

Despite some of the shortcomings of the Farm Bill and other older pieces of agricultural legislation, it is not reasonable to dismiss all existing policy programs as outdated and insufficient. Over the near century of its existence, the Farm Bill has proved instrumental in the establishment of several government programs that have been critical for supporting food producers as the global landscape has modernized and shifted alongside a greater understanding of the environmental impact of industrial agriculture. These range in focus from strict conservation measures to recognizing the importance of soil health, as with the Soil Conservation and Domestic Allotment Act, to creating incentives for maintaining natural resources.

One of the longer-running examples of these programs is the Conservation Reserve Program (CRP), established in 1985 as an offshoot of the conservation title included in Farm Bills extending back to the Agricultural Act of 1956 which introduced the Soil Bank Program (Helms, 1985). While the primary goal of this program was to reduce the acreage of commodity crops to maintain farm income by limiting supply under the Acreage Reduction Program (ARP), it also included the nascent CRP, which sought multi-year contracts financing the conversion of agricultural land into pasture, range, forest, and wildlife uses (Helms, 1985). While eligibility

and insufficient fund concerns arose initially, with time the program proved to be a moderate success, especially in the conversion of lands most heavily eroded as a result of industrial agriculture. After the initial contracts expired in 1970, CRP was formally authorized in the Food Security Act of 1985 (Stubbs, 2014). Today, the Farm Service Agency, a branch of the USDA, continues to operate this program, with the goal of offering annual rental payments for farmers that improve the environmental outcomes on land which has become environmentally sensitive because of agricultural production (USDA, 2025) This aligns directly with regenerative goals, improving land use, directly considering environmental impacts, and acting to improve biodiversity in formerly heavily managed areas. Expansion and restructuring of this program could extend beyond relatively passive conservation and complete retirement and instead allow for continued sustainable use under specified regenerative and environmental criteria.

Similarly, the Environmental Quality Incentives Program (EQIP) was part of the 1996 Farm Bill and functionally served to combine a series of existing programs, including the Agricultural Conservation Program, the Water Quality Incentives Program, the Great Plains Conservation Program, and the Colorado River Salinity Control Program (Hebblethwaite & Somody, 2008). Similar to the CRP, this is a voluntary public program that allows food producers to receive financial and technical assistance for improving the conservation of soil and water resources on their land (Stubbs, 2010). This program is broad in scope and is currently the largest program available for providing financial assistance to agricultural land conservation. Some of the conservation practices supported by this program include implementing crop rotation, introducing pollinator species, improving nutrient management, and improving irrigation efficiency (*Environmental Quality Incentives Program*, 2019), all of which are also supported under regenerative agricultural approaches. The downside of this program is that funds

are limited and competitive, with many producers being denied access. Although there are stipulations for a small portion of the funds to be awarded to beginning and disadvantaged farmers, the EQIP has been criticized for perpetuating the bias toward large producers associated with broader farm subsidies. Some critics have also suggested that the funds are not being allocated in such a way as to functionally optimize environmental benefits (U.S. GAO, 2017), leaving room for improvement both in environmental outcomes and equitable processes.

Finally and most recently, the 2008 Farm Bill, also known as the Food, Conservation, and Energy Act of 2008, focused more closely than past bills on the environment and consumers, in turn reducing the "safety net" provisions of previous farm subsidy programs (Harris et al., 2008). This was the first farm bill to include Horticulture and Organic Agriculture as one of its titles, demonstrating the march of progress in understanding the impacts of industrial agriculture. It maintained a majority of funding for nutrition programs while shifting some of the funds used for crop insurance and commodity subsidies to contribute to aforementioned programs like EQIP and other conservation focused initiatives. Additionally, provisions included within the bill tweak the FCIP to accord "special treatment of organic farmers" (Harris et al., 2008, p. 19), specifically within Sec. 1238E., the Conservation Stewardship Program (CSP), establishing "a transparent means by which producers may initiate organic certification under the Organic Foods Production Act of 1990" (Peterson, 2008, p. 1045).

It is important to distinguish here that the term organic is frequently misunderstood and misused across the food industry, and in the policy context refers specifically to a series of specifications laid out in the Organic Foods Production Act, which considers factors such as pesticide application and fertilizer use (Organic Foods Production Act, 2005). While this represents an improvement from historic practices and regulations, in practice the term organic is

a USDA label for products that meet specified criteria that focus largely on the use of synthetic materials in food production. This is distinct from regenerative approaches, which may also avoid synthetic chemicals and materials, but also go beyond organic requirements to consider not just the process of food production but also the larger context of the land and environment in which the food is being grown (Noble Research Institute, 2021). Despite this distinction, the CSP represented another significant milestone in the gradual transition of the American agricultural landscape into a more environmentally attuned direction. This program helped further lay out a groundwork for modern conservation processes and standards for environmental impact but fell short of making them sufficiently scalable, and did little to address those producers content to remain outside the scope of organic labelling and these programs.

4.3 Proposed Changes to Policy

Section 4.2 serves to demonstrate that a "regenerative revolution" to modern US agriculture need not start from ground zero. There are important and impactful existing policies, some of which date back nearly a century, that lay out precedents and foundations upon which more sustainable regulations and programs can be established and broadened. Using the examples and practices characteristic of regenerative agriculture, modifications to existing policy and the creation of new policy could transform the American agricultural landscape across a relatively short timescale. Such a transformation would allow the US to drastically reduce its contributions to greenhouse gas emissions, create a more equitable, sustainable, and healthier national food system. It would also make the United States a global leader in sustainability within the agricultural sector, offering an example to other industrialized nations and demonstrating that countries need not sacrifice sustainability in exchange for sufficient production of food.

In order for these changes to be functional and effective, they must be enacted on a series of scales. The existing Farm Bill sets a backdrop for federal policy to inform implementation of regenerative approaches into agricultural legislation, and will be a critical component of this transition. Section 4.3.1 will lay out major policy measures to be implemented at this scale, including national standards for environmental impacts, reprovisioning of funds to better support smaller and more sustainable food producers, and the decoupling of legislation from major food corporations ("big agribusiness"). However, the emphasis on local context that underscores regenerative principles demands additional changes be proposed and implemented at sub-national levels. It is beyond the scope of this paper to offer a state-by-state analysis according to ecoregions, trends in climate, and existing policies. However, section 4.3.2 will discuss some major existing state policies and offer insights into how state level policy may be advanced. Section 4.3.3 will then go further, examining the role of the private sector in accompanying public efforts to advance a more sustainable food system. Lastly, section 4.4 will offer a comparative analysis of two states with economies dependent on food production on seemingly opposite sides of the regenerative transition, California and Iowa, to demonstrate how sustainable agricultural practices can be incorporated into two different political, economic, and ecological contexts.

4.3.1 National Level Solutions

The Farm Bill has been the foundation of agricultural policy for nearly a century, serving to support farmers and food producers in the face of economic and environmental pressures. Due to its regular renewal timeline, this piece of legislation holds significant potential for contributing to the future of sustainable American agriculture, more so than any other existing policy framework (McConville et al., 2023). It also provides an existing platform and a precedent of

shifting finances and priorities in response to the needs of the country and agriculture at different points in time. Thus, policy suggestions aiming to significantly address the country's entire system of food production are most probable, enforceable, and effective via this Act. Furthermore, as mentioned, the Farm Bill is up for renewal at the end of 2025, after being extended for the second time in December of 2024. This means, both, that existing legislation encoded by this act has not been updated since 2018 (meaning it was drafted in 2017) and has thus grown increasingly out of touch with the pressures of today, and that the time is ripe for implementing sustainable policy that will last until 2030, a landmark year for national and global climate goals.

One of the most glaring and straightforward pieces of policy that could drive progress toward achieving a regenerative transition is establishing a definition and set of criteria that allow farms and products to be recognized by a nationally recognized label of "regenerative," similar to what has been done for the term "organic" by the Organic Foods Production Act of 1990. This would cement this term into agricultural policy and give it a level of weight and consensus that would advance both sub-national policy and farm-level action toward a national standard. At present, there is no legal national definition or recognition of what regenerative means, allowing producers and food labels to use the term freely. As of January 2025, the first recommendation for a definition of the term regenerative was proposed to the California Department of Food and Agriculture by the California State Board of Food and Agriculture, the product of over a year of workshopping and development (full text in Appendix A) (CDFA, 2025b). Even this definition, though, is intended only as a means of informing state agencies of the meaning of the term as it pertains to state policies and programs, and importantly, "is not a definition for certification or a recommendation for incorporation into state statute" (Cameron,

2025, para. 2). The Farm Bill could be the most promising piece of legislation for establishing a definition that is explicitly intended for incorporation into state statutes.

In order to incorporate a national definition of regenerative agriculture into the next iteration of the Farm Bill, it must be simplified into the broadest strokes and practices that are relevant across contexts without sacrificing the impacts of proper regenerative approaches. Following the example from the California State Board of Food and Agriculture, this definition should provide a baseline like the one offered in Section 2.3.2 alongside a series of criteria, including specific reference to the following principles:

a) Practices promoting improvements in **soil health** over time, including reducing disturbance, maintaining coverage, reducing erosion, and improving water retention
b) Practices encouraging the **sequestration of carbon** in the form of soil organic carbon (SOC)
c) Minimizing the addition of **external inputs**, including chemical biocides and synthetic fertilizers
d) Incorporating a **diversity of crops** and breaking down dependency on monocultures
e) Reducing **runoff** from agricultural lands, both by improving the retention rates of soils and by eliminating harmful nitrogen and phosphorus leakage
f) Engaging with and acknowledging the influence of **Indigenous practices**, including land acknowledgements and tribal partnerships
g) Promoting **locality** in sales and distribution of crops
h) Improving the **resilience** of agricultural lands to climate change and variability

Having established a definition and outlined some of the criteria, the Farm Bill can establish a framework for providing regenerative verification that meets minimum standards by

state and by establishing an agency for reviewing and verifying data, which can draw on existing programs like EQIP to offer soil quality testing, water monitoring, and other tools for assessing performance toward environmental criteria. This program could potentially function in a similar way as the Growing Climate Solutions Act, through which the USDA established a voluntary Greenhouse Gas Technical Assistance Provider and Third-Party Verifier Certification Program. These programs facilitate verification and establishment of carbon credits for producers "carrying out sustainable land use management practices that prevent, reduce, or mitigate greenhouse gas emissions, or sequester carbon" (Sen. Braun, 2021, Sec. 2.b). However, there are grounded concerns about the lack of transparency provided by third party testing and verification. Ideally, the USDA would publicly manage verifying and certifying producers as regenerative, but this would hugely limit the scope and rate at which verification could realistically take place. One possible solution to mediate the concerns about transparency in the verification process to ensure equity and avoid malfeasance would be to link data collected by verifiers to academic centers or research facilities, which could simultaneously produce research improving the quality of knowledge about the efficacy and impacts of regenerative approaches while also acting as an accountability mechanism to ensure accuracy in reporting and verification of regenerative producers. In the same vein, national establishment and verification mechanisms for regenerative producers could expand upon the existing Third-Party Verifier Certification Program to better acknowledge and incentivize regenerative approaches to food production.

Funding provided by the Farm Bill should also be allocated to support research into regenerative technologies and strategies to reduce the economic and technical burden of shifting to more sustainable practices, including the repurposing of industrial equipment (*Innovative Farming Solutions*, 2024). There are a number of options for establishing funding sources for

programs supporting a regenerative transition to complement those that exist. Subsidies are an industry norm for farmers, and instituting a transition to gradually shift funds from programs like FCIP and other subsidies for major crops to subsidizing crop diversification, practices like no till, cover cropping, agroforestry, and increased environmental monitoring is one possible route. If implemented at a gradual pace, for example, a reappropriation of even 15% of funds from FCIP to a Regenerative Agriculture Subsidy Program (RASP), over the course of ten years over $2.5 billion in funding could be unlocked while still leaving almost $15 billion (based on the 2022 budget of $17.3 billion) for producers dependent on the FCIP or otherwise unable or unwilling to make use of RASP (U.S. GAO, 2023). Reforming and repurposing crop insurance programs to better reward regenerative approaches over time will be fundamental to incentivizing farmers to shift their practices and provide sufficient financial support to do so.

Gradually transitioning funds from existing subsidies may be politically challenging, however, as there will almost certainly be significant opposition to the appropriation of funds away from major players in the food and agriculture space. Significant amounts of money and energy are directed towards lobbying each time the Farm Bill is up for renewal, with the Union of Concerned Scientists estimating over $500 million spent by industry stakeholders and big agribusiness actors since 2018 on lobbying for the next iteration of the Farm Bill (Sebastian, 2024). This comes in addition to significant donations to the campaigns of key legislators involved with the major piece of agricultural legislation in that same time period. Importantly, many of these major actors are those benefiting from both current industrial practices and the support of federal subsidies for commodity crops. For example, the American Farm Bureau Federation, a climate change denying organization with ties to oil which has tried to minimize the stringency of GHG reporting is estimated to have spent over $15 million on lobbying over

the five-year period of the last Farm Bill (Sebastian, 2024; Banerjee et al., 2018). Organizations like this and others represent significant and powerful forces motivating the passing of agricultural policy, and are likely to act against the redirection of funds for regenerative approaches that don't align with their practices and business models.

Despite the outstated standings of these major organizations, there is potential for action to come about in advocating for shifting trends in funding through major legislation like the Farm Bill. Coalitions and other collaborations between smaller groups, if sufficiently focused and united around a common goal, can bring together a not insignificant amount of political pressure and influence. For example, after the 2018 Farm Bill was extended for the first time in 2023, over 100 organizations came together to write a letter to House and Senate Agriculture Committee leadership, identifying 34 bills that could be incorporated into the next edition of the Farm Bill, to "help transform the U.S. food and agriculture system into one that is more sustainable, resilient and equitable, and that farmers, workers, and communities need and deserve" (Sebastian, 2023, para. 2). Bringing together smaller producers alongside non-profit organizations and advocacy groups represents one potential route to countering the influence of the lobbying powers of big agribusiness, although they will remain hard-pressed to compete financially. This may suggest a need for considering alternative funding mechanisms for these transition programs, perhaps in partnership with more private sector actors, as will be discussed in section 4.3.3. Other solutions to mitigate the presence and pressures of lobbying from industrial agriculture supporters include focusing funding toward research and development for regenerative agriculture, which may be less polarizing and reduce transition costs in the long-run (Heyl et al., 2022). Alternative financial instruments could also be built out to more closely marry regenerative approaches with carbon markets and trading, which has been accepted by

industrial agriculture. Making existing subsidy programs more narrowly focused and incorporating clauses that stipulate minimum standards of environmental impact could also create an incentive to shift to more sustainable practice without explicitly redirecting funds away from current large-scale producers. Regardless of the approach, though, financing schemes for these programs will inherently be an uphill battle, and will require dedicated attention and adaptability.

In addition to these financing mechanisms, the next iteration of the Farm Bill ought to incorporate a methodology for acknowledging the economic costs associated with damaging environmental resources, referred to as True Cost Accounting (TCA) (Gemmill-Herren et al., 2021). The concept of TCA has emerged across sectors as consumers and markets have become more motivated by social and environmental values. This methodology aims "to measure and value the positive and negative environmental, social, health and economic costs and benefits to facilitate business, consumer, investor and/or policy decisions" and thus offers a guiding principle by which the government can motivate more sustainable practices by reflecting their "true costs" and internalizing them for producers rather than having consumers bear the costs (de Adelhart Toorop et al., 2021, p. 655). Programs like TEEBAgriFood (the Economics of Ecosystems and Biodiversity for Agriculture and Food program) created by the European Commission have worked with governments specifically examining livestock operations "to provide a comprehensive economic evaluation of eco-agri-food systems, and demonstrate that the economic environment in which farmers operate is distorted by significant externalities" (Baltussen et al., 2016, p. 4). A national farm policy could establish a similar research program to be organized in the United States, with the results being used to reevaluate practices supported

by government funding and to produce more effective economic policy to promote a transition to regenerative practices that better reduce environmental costs.

The list could go on; there are near infinite different policies and actions taken in permutation that could accelerate a regenerative revolution. Those described above are some of the most general and simultaneously most likely to be effective and enactable. However, there exist some underlying assumptions behind these suggestions and significant barriers to enacting policies like those described in this section. For one, they assume there will be minimal political resistance, which is almost certainly false. They also assume a level of cooperation and bipartisan support for a progressive and sustainable Farm Bill and other national policies that does not accurately reflect the present political climate of the nation. Lastly, they fail to acknowledge the powerful influence of industrial agriculture groups discussed in influencing policymakers and food producers.

There is no simple solution to overcoming these challenges. The second Trump administration has built a clear platform on deregulating the agricultural sector and overturning critical climate regulations (Zimmerman, 2023). On a broader scale, there has been a clear trend of weakening of infrastructure, including the USDA, which removed data from public sites pertaining to climate change, depriving farmers of "information about federal loans and other forms of assistance" (Garza, 2025, para. 3). The USDA should be expected to become less flexible and increasingly limited in its ability to promote climate-related goals and programs. Addressing this issue in the context of a regenerative transition will likely require strategic framing of practices and their benefits for food producers in the nation. Rather than emphasizing the improvements in GHG emissions or carbon sequestration, proponents may instead focus on communicating the reduced need for chemical inputs and improvements in water retention and

soil health which may be able to circumvent the destabilized attitude toward climate change upheld by the present administration. As a whole, though, US political infrastructure is in an unprecedented state of uncertainty and destabilization, which will certainly alter both the methods and likely outcomes of a regenerative transition. Programs with an explicit emphasis on climate change and emissions mitigation are unlikely to be achieved, while those which support food producers and can be framed as reducing costs may be more feasible.

It is thus highly unlikely that the next iteration of the Farm Bill will pass sweeping sustainable legislation. However, the solutions and proposals offered in this chapter will remain relevant when the next Farm Bill expires, and the following, and the following. The question is not if these policies should be implemented to achieve a more sustainable agricultural and food system in the US, but how soon. Five more years could send the nation further into an entrenched industrial agriculture landscape, and continue to drive up global GHG emissions, failing to make significant progress in the agricultural sector on climate goals. However, the problem will persist until large-scale government intervention occurs. Given that this may not be likely in the immediate future, it is important to consider other levels where change can be enacted.

4.3.2 State-Level Initiatives

While the Farm Bill and other national-level policy improvements could contribute significantly toward a regenerative transition, state-level initiatives will also be critical, especially in light of the varying ecologies of different states and different needs of producers based on subnational trends in climate change and variability. Furthermore, states are afforded more freedom to pass legislation on a faster time scale than the national government, and with less red tape and changing-of-hands than characterizes national policy. Some initiatives could be

newly established in conjunction with the proposed policy changes outlined in the previous section at the national scale. Others, though, will be most effectively managed at the state level. A number of examples of these state-level programs exist already, and will be discussed here as models for other states and entry points for further advancing sustainable agriculture.

One of the tenets of regenerative agriculture is soil health, which when maintained can effectively sequester carbon, reduce greenhouse gases, hold more moisture, and remain resilient to drought and erosion. The California Healthy Soils Initiative addresses this goal in advancing sustainable agriculture goals within the state, combining resources from different state agencies and departments to support practices promoting healthy soil by food producers. Funded in part by the EQIP discussed previously, as well as discretionary funding by the state through the Healthy Soils Program (HSP), this initiative showcases the benefits of healthy soils and also supports the development of "a regulatory pathway to address permitting challenges and create incentives to support on-farm composting of agricultural materials" (CDFA, 2025a, para. 2). This marks a concrete commitment by the state to a broader goal of Climate Smart Agriculture (CSA), and exists alongside a number of other programs, making California a leader in the nation for commitments to sustainable agricultural practices (see Section 4.4.1). Furthermore, this program holds potential to expand, including by providing education and technical assistance to farmers interested in improving the quality of the soil of their lands which could be achieved through a regenerative approach. For example, no till practices and the application of compost, manure, and other natural fertilizers improve the quality of the land without requiring artificial inputs. While at present this program can only offer incentives and thus requires a willingness from producers to transition, a combination of educational campaigns and baseline

requirements for monitoring and reporting soil quality could rapidly advance the impact of this initiative while simultaneously providing a model for other states to adopt.

Michigan offers another example of a similar state-run initiative promoting sustainable practices in alignment with regenerative principles. The Michigan Agriculture Environmental Assurance Program (MAEAP) provides verifications to farms meeting specific standards based on environmental impact and supports food producers interested in making changes to meet these standards. As with California, the state builds off the foundation established by the NRCS and includes provisions for conservation measures "to reduce soil erosion, prevent water pollution, and mitigate other environmental risks" (Michigan Agriculture Environmental Assurance Program, 2023, para. 2), and reports annual improvements in environmental impact based on criteria like acres under a nutrient management plan, reduction in sediment reaching waterways (erosion control), and volume of nitrogen and phosphorus leaving fields (nutrient cycling). While still a relatively new program, this initiative shows promise for growth. As of 2023, 2.1% of Michigan's cropland was verified or reverified, representing a small fraction but indicating significant room for improvement (Michigan Agriculture Environmental Assurance Program, 2023). The addition of further incentives beyond those that exist, which include regulatory protection and preference in consideration for technical assistance, as well as the introduction of disincentives or taxes for negative impacts could expedite the rate of transition for farms in the state. For example, the introduction of a fee per ton of sediment reaching waterways could drive producers to strive to maintain more strict anti-erosion practices to minimize environmental impacts, which could take the form of regenerative approaches like maintaining soil coverage and year-round roots in the soil. Michigan thus provides another example for other states in a completely different ecoregion than California as well as a

demonstration of how positive incentives can encourage sustainable modifications from food producers.

Some states are working more closely with the existing system outlined by the Farm Bill and other precedents of agricultural policy to support farmers in more sustainable practices. Iowa, for example, offers a Crop Insurance Discount Program specifically tailored to support the use of cover crops by farmers. This program offers $5/acre toward cover crops for eligible farmers, which, as touched on in the previous chapter, supports year-round growth in agricultural soils, thereby supporting the integrity of soils and constant rather than seasonal sequestration of carbon. Furthermore, this program builds upon the FCIP that farmers and food producers have long understood as a source of support for their land, breaking down barriers to adoption and creating a clear incentive for transitioning toward a more regenerative practice of crop planting. According to the state, this program acknowledges "a steep learning curve for individual farmers to adopt new practices" (Clean Water Iowa, n.d., p. 2) and strives to make the adoption of more sustainable practices more economically feasible, supported by funds from the USDA Risk Management Agency (RMA). This learning curve is a very real barrier for many food producers, who are frequently risk averse and hesitant to make significant changes to their practices for fear of reduced yields or unforeseen consequences. Acknowledging and addressing this behavioral resistance or broader hesitance to take a risk on adopting a more sustainable practice and offering a financial incentive is a critical tool for facilitating a regenerative transition.

These are just a few examples from a small sample of states highlighting the potential for state-level policies and initiatives to promote regenerative practices to improve the sustainability and minimize the environmental impact of food production. Building upon these state-by-state examples, it is possible to extract themes that can be adopted by other states. Drawing upon these

existing programs, and the creation of similar initiatives to address other positive aspects of regenerative agriculture like biodiversity, synthesized templates can be established to form State Transition to Regenerative Agriculture Programs (STRAPs). These STRAPs can build off the examples discussed above and others to create baseline standards for various environmental impact criteria, for example;

- Statewide **monitoring and reporting** of land use for agriculture, including minimum standards for environmental impact and biodiversity
- Monitoring of **greenhouse gas emissions** by farms verified by state agencies, to be used toward climate policy programs like carbon taxes or incorporation into state- or region-wide carbon markets
- **Soil quality** scores as assessed by regulatory agencies, with financial incentives and verification programs with associated benefits for improving soil quality
- Fees or taxes for estimations of nutrient runoff traceable to food producers, which could in turn be used to fund programs providing **technical and financial support** for transitioning toward more regenerative agriculture

These are just a few of the possible standards that could be included in a template policy for states to implement and modify based on their specific needs, climate, and existing policy and regulatory infrastructure. Even with the successful implementation of such programs, problems are likely to arise similar to those faced by the existing system of sustainable food production in the US. For example, funding for these programs will not be infinite, and will likely vary based on the passage of various national and state legislation year-to-year. Selection and distribution of funds from these programs will have to be managed carefully to avoid

preferential treatment toward large producers, and thus should also include stipulations promoting support toward smaller farms and those most sensitive to climate change.

For both existing programs and proposed examples like STRAP, federal-state collaboration is a necessary piece for successful implementation. Collaboration with agencies like the USDA, NRCS, and other federal agencies forms a key pillar of the transition toward more sustainable agricultural policy. Expansion of these collaborations would be beneficial to promoting a more rapid and effective regenerative transition, and could take a range of forms. Matching grants, for example, could be offered proportionally to states to reduce the financial burden of supporting programs that incentivize regenerative agriculture practices. Federal pilot programs could also be introduced in selected states to test policies and optimize initiatives before incorporating them into state agricultural policy. This could also encourage states to apply for funding to experiment with different regenerative models with the goal of providing scalable frameworks that could eventually be adopted on the national level. In this way, state-level policy forms an essential part of the equation for advancing sustainable policy reform in the agricultural sector in the US, complementary to national policy changes.

4.3.3 Interactions with the Private Sector

While the focus of this thesis addresses the role of policy in supporting a regenerative transition to improve the sustainability of the American food system, it is impossible to propose solutions that disregard the role of the private sector. The private sector, which includes the loosely defined “agribusiness” sector, transnational food corporations, and global distributors, holds a significant level of influence over food production. Effective policy suggestions must consider these entities to effectively drive systemic change in the food system. For one, the private sector is a major source of technological innovation and investment for novel agricultural

practices, even those under regenerative agriculture which can be achieved through relatively simple measures. Furthermore, most agricultural enterprises in the US are privately owned, meaning attempting to improve sustainability without considering private economic interests could cause unintended economic consequences. Given the risk-averse nature of food producers in the US, negative economic consequences of policies supporting regenerative approaches could be counter-productive and act to discourage the adoption of more sustainable practices. It is thus necessary to briefly consider the role of the private sector in conjunction with policy initiatives.

First, it is worthwhile to consider the existing role of actors in the private sector in supporting a transition towards regenerative agriculture. In recent years, there has been growing interest in regenerative practices among corporations involved in the food system as part of internal sustainability goals, value alignment with missions, and for a competitive edge to appeal to eco-conscious consumers. The largest and most prominent example of this in the United States is a joint commitment by Walmart and General Mills to support the growth of regenerative agriculture across 600,000 acres by 2030 (Walmart, 2023). According to the multinational retail corporation, this specific area target corresponds to "the approximate number of acres General Mills engages in sourcing key ingredients for its products sold through Walmart and Sam's Club" (Walmart, 2023, para. 1) thus representing an effort to improve the sustainability of Walmart's supply chain. Additional funding has been sought through government grants from the National Fish and Wildlife Foundation (NFWF). These major corporations have chosen to adopt regenerative agriculture specifically due to its ability to "address climate change and create positive outcomes for both people and our planet," and in doing so purportedly seek to "build on organizational commitments and leverage collaboration to help spur industry-wide change" (Walmart, 2023, para. 3).

At a glance, this appears to be a landmark commitment to scaling up regenerative agriculture, with a source of financial support that is unlikely to be available through public funding. As the largest grocery store in the country, Walmart holds significant influence over trends both among retailers and consumers and has made a point to publicly commit to various sustainable initiatives. Beyond the partnered commitment with General Mills, Walmart has also committed $120 million alongside PepsiCo toward healthier soil and water practices on farms and has striven to incorporate regenerative and sustainable agriculture practices across 10,000 acres of its own private-label rice (Zimmerman, 2023). All of these changes follow a commitment by the major retail provider to becoming a "regenerative company" in 2020 (McLaughlin, 2023). If Walmart is successful in this goal, it could very well establish a new baseline for value alignment among food providers, especially alongside its continued dedication to being a low-cost provider. It is critical to understand the scope of this commitment; to achieve these goals on these timelines, agricultural supply chains will need to be downsized, formerly externalized costs will need to be incorporated into the margins, and pricing will have to shift to accommodate and accurately reflect these changes (Held, 2023).

Several concerns arise in considering the feasibility and implications of large corporate commitments like this. For one, how Walmart chooses to define 'regenerative' is up to their own discretion, and could result in producing an industry standard that meets the bare minimum requirements for the brand, effectively watering down the term and opening the door for other companies to market themselves as such without making significant changes. Additionally, the scale of companies like Walmart means it is unlikely they will be seeking out small- to midsize farms, where a majority of regenerative agriculture is taking place. Instead, it is likely that the company will follow the same pattern as when it made commitments to offering low-cost organic

options for consumers; rather than shifting its sourcing strategy to prioritize existing small-scale organic producers, the company helped establish industrialized organic farms. This seemingly contradictory trend has also been called “big box” organic and is a result of Walmart helping large existing commercial operations to meet the minimum requirements for USA certification (removing chemical pesticides and fertilizers) without making substantial changes otherwise (Held, 2023; Cronin, 2022). The low price point of these commercial operations makes them incredibly competitive, pushing other companies to adopt similar practices. For regenerative agriculture, which thus far has remained on the outskirts of large corporate practice and adoption, this could represent a critical tipping point for the future of the label “regenerative,” and runs the risk of reducing it to a minimum standard, especially considering there is a present lack of regulation by the USDA.

One element of the Walmart case that does hold potential is the combination of public and private investment and funding sources into regenerative agriculture commitments. This corresponds more broadly to the promise of collaboration between government and private entities to enter into public-private partnerships. By combining multiple stakeholders, these partnerships open the door to a much greater array of funding opportunities, “mobilizing public and private capital to support sustainable agriculture initiatives” (Sustainable Agriculture Network, 2024, para. 1). Private companies, as seen in the example of Walmart, are feeling more and more pressure to develop robust environmental and social goals. Public funding sources can be joined with investment and financing initiatives from the private sector to offer a blended finance approach to supporting the adoption of regenerative practices by food producers. Furthermore, by collaborating, public-private partnerships create a dialogue between governments and actors in the private sector, helping to “develop evidence-based policies that

promote sustainability, resilience, and inclusivity in the agricultural sector" (Sustainable Agriculture Network, 2024, para. 5). In practice, the public sector can create positive incentives for farmers and food producers to shift toward more regenerative approaches, while the private sector can act as the proverbial stick, preferentially shifting sourcing and driving lower prices in the regenerative sector, making it more competitive in the market (Aarup-Andersen, 2023). For example, a blended finance approach could be used to provide funding mechanisms necessary to scale up critical infrastructure for a large-scale regenerative food system, including soil testing labs, programs for educating farmers, and logistical support in the form of distribution networks. Public-private partnerships have already been used in other countries like the Netherlands and Brazil to support the advancement of regenerative agriculture, laying out a precedent for the US to follow (Zandt et al., 2023; Cherubin et al., 2024). If executed properly, these two forces can functionally balance each other, promoting a much more rapid adoption of regenerative agriculture, and incentivizing the phasing out of much less sustainable industrial agriculture norms and practices.

As discussed in the case of Walmart, there are significant challenges and risks associated with involving the private sector in promoting the adoption and scaling up of regenerative agriculture. Greenwashing, for example, is a major concern in incorporating the private sector into sustainability initiatives, and could easily become widespread given the nebulous nature of the term "regenerative agriculture," effectively diluting the term completely. It can also be misleading to consumers, leading them to choose low-price items from large-scale operations claiming to be regenerative, causing smaller and more locally-based regenerative operations to suffer, forcing them to sell to distributors or implement non-regenerative practices to be more competitive or receive support from government initiatives like FCIP. There is also a concerning

lack of transparency in corporate sustainability claims. Even when companies are not fully duplicitous (although this is a concern), there may be inconsistencies between public-facing claims and advertising and the actual practices or changes made internally. It is also not uncommon for companies to manipulate information or bury failures to achieve goals to remain in the public favor.

Addressing these issues can be another product of merging private and public sectors to achieve effective sustainable reforms. As environmental commitments have become more common among companies as a broader trend of Corporate Social Responsibility (CSR), there has been a coincident push for legal enforcement mechanisms to ensure accurate reporting of progress. Public policies can be a critical tool for enforcing accountability at both the national and sub-national levels. These may take the form of negative reinforcement, whereby companies are randomly audited to verify compliance and fined if public agencies identify discrepancies between their reported and actual data, for example in GHG emissions. However, these can also be done through positive mechanisms, such as offering certification systems, similar to existing systems for terms like “organic,” to encourage accurate reporting and reform to obtain a legally defined regenerative certification. Financial incentives can also promote accurate reporting and transparency, including through tradable carbon or soil credits, or preference for participation in various government programs to encourage private companies to report accurate and significant progress toward regenerative standards.

In general, there is reason to be wary of the involvement of the private sector in the regenerative transition in US agriculture. For as long as companies are driven to produce, distribute, and sell as much food as possible at the lowest price point, their practices are likely to run counter to sustainable practices. However, there is a growing body of evidence for the

effective incorporation of private influence into supporting more sustainable agriculture practices and a particular engagement with the notion of a regenerative approach. Through public-private partnerships and strict accountability mechanisms, the private sector can complement the advancement of national and state policy to promote a regenerative transition. It will be even more critical for policy instruments to address economic concerns in this case, as this is sure to be a determining factor for adoption by private actors, in addition to the existing concerns among farmers and food producers themselves.

4.4 Comparative Analysis of Two Distinct Regions

To highlight the interaction between national and state-level public policy changes, the private sector, and existing producers in the food system, two states will be employed as case studies for how regenerative agriculture may be implemented. California is the country's largest producer of agricultural products, bringing in billions of dollars across the state, as shown in Figure 9, and representing roughly a tenth of the national total sales value (Scott, 2024). While there is no existing metric for sustainable agriculture, California is also one of the leaders in organic farming in proportion to the scale of food production, leading the nation in the number of organic-certified farms, with over 3,000 spanning over one million acres (Commodity.com, 2022). It thus represents as an example of a state with a demonstrated interest in more sustainable practices that has already made significant progress and effort toward a regenerative transformation. Iowa is also one of the nation's largest producers, trailing only California. However, in stark contrast to the West Coast state, Iowa has lagged far behind in making sustainable improvements to its agricultural model, having been deemed both the "beating heart of the Corn Belt" and "epitome of the industrialized agriculture model" (Perry Stillerman, 2018, para. 18).

These two states also make for a stark comparison; California sits on the West Coast and houses a huge variety of ecosystems across the state. Iowa on the other hand, sits in the center of the country and used to be predominantly prairie, although estimates by Iowa State University identify “prairie land cover in Iowa has been reduced to less than 0.1% of its original extent” (ISU Extension and Outreach, n.d., para. 1), with the largest driver of loss being agriculture. Furthermore, California is frequently cited as one of the most politically liberal states, compared to Iowa which, while not at the extreme, tends to be right of center. These two states are thus fitting for demonstrating how regenerative agriculture can be effectively incorporated into very different ecological, social, and political climates while still maintaining volumes of food production.

4.4.1 California

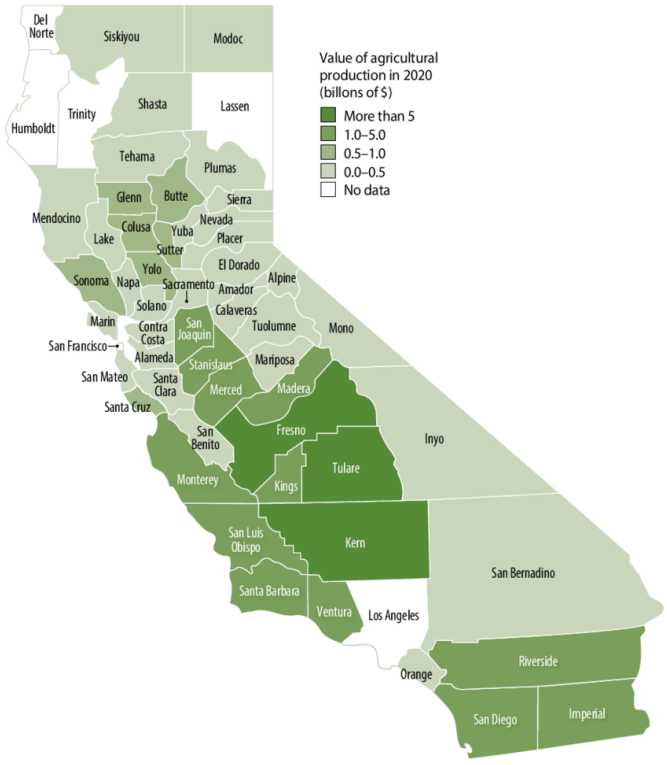


Figure 9. The value of agricultural production in 2020 by county in California, with a concentration around the Central Valley. Reprinted from "More Jobs and Less Seasonal Employment in California Agriculture Since 1990," by Z. Rutledge & P. Martin, 2023, *California Agriculture, 77*(2), pp. 1–8 (https://doi.org/10.3733/ca.2023a0008). Copyright 2023 by The Regents of the University of California.

California is a critical component of the American food system, and simultaneously one of the most sensitive to climate change; wildfires and droughts have become expected in recent years, threatening the capital of agriculture in the US. California is also the national leader in GDP and population. A rich variety of factors thus play a role into its state policies and practices, especially when it comes to agriculture and food production. Even in previous sections, California has already emerged as a leader in the regenerative (or more broadly, sustainable) agriculture transition, as demonstrated by programs like the Healthy Soils Initiative and the first proposed definition of the term regenerative for legal reference. As such, the state is poised for making strides toward a regenerative revolution.

Firstly, existing policies align well with regenerative goals. The HSP represents a recognition of and commitment to regenerating the most fundamental and frequently discounted natural resource for agriculture: healthy soils. This is one of the most fundamental tenets of regenerative agriculture and has been understood for over a century. Sir Albert Howard, featured in both the Introduction and opening quote for Chapter 1, wrote at length about the importance of maintaining healthy soils for productive and sustainable agricultural practices. According to the soil scholar,

> "Soil fertility is the condition which results from the operation of Nature's round, from the orderly revolution of the wheel of life, from the adoption and faithful execution of the first principle of agriculture -- there must always be a perfect balance between the processes of growth and the processes of decay" (Howard, 1940, p. 35).

Protecting the health and fertility of California's soils is not a unique feature of regenerative agriculture, but it does represent a foundation upon which further regenerative

practices can be applied. Methods of production like no-till and cover cropping contribute to the health of soils, with important co-benefits like the sequestration of carbon, improved water retention, and increased biodiversity.

Beyond California's HSP, there are a number of other sustainable agricultural practices and policies that are well aligned with regenerative goals.

Table 2. A summary of prominent policies associated with Climate Smart Agriculture in the state of California, including their scale, funding, and associated agencies. Reprinted from "The Policy Enabling Environment for Climate Smart Agriculture: A Case Study of California," by J. Lewis & J. Rudnick, 2019, *Frontiers in Sustainable Food Systems, 3*, Article 31 (https://doi.org/10.3389/fsufs.2019.00031). Licensed under CC BY 4.0.

CSA program	Program goals	Existing projects	GHG reductions (MT = metric ton)	Administering agency	Funding to date (2018)
Alternative Manure Management Program (AMMP) and Dairy Digester Research and Development Program	Reduce GHG emissions from animal operations and manure by installing digesters or implementing alternative manure management strategies	AMMP: 58 projects DDRDP: projects on 17 farms in 7 counties	>360,000MT CO_2e reductions over 10 years	Department of Food and Agriculture	$260 million
Funding Agricultural Replacement Measures for Emission Reductions Program (FARMER)	Grants, rebates, incentives for efficient agricultural heavy-duty machinery and equipment (harvesting, trucks, agricultural pump engines, tractors etc.)	2018 is first year	N/A	Air Resources Board and local air districts	$197 million
Food Production Investment Program	Incentives to food processors; efficient processing technologies	2018 is first year	N/A	California Energy Commission	$124 million
Renewable Energy for Agriculture Program	Installation of on-site renewable energy technologies in agricultural operations	2019 is first year	N/A	California Energy Commission	$10 million
Sustainable Agriculture Lands Conservation (SALC) Program	Reduce GHG emissions associated with urban sprawl & ag land conservation; fund ag easements	Projects covering 80,000 acres in 25 counties	42 million MT CO_2e reductions over 30 years	Department of Conservation & Strategic Growth Council	$73 million
State Water Efficiency and Enhancement Program (SWEEP)	Update irrigation systems to improve efficiency to save energy (reduce GHGs) and conserve water	Projects on 606 farms in 33 counties	>300,000MT CO_2e reductions over 10 years	Department of Food and Agriculture	$66 million
Healthy Soils Initiative	Incentivize adoption of best practices to store carbon in soil (sequestration), reduce soil erosion & increase water holding capacity	Projects on 86 farms in 31 counties	>115,000 $MTCO_2e$ reductions over 10 years	Department of Food and Agriculture	$13 million

State Greenhouse Gas Reduction Funds have been used to fund the listed CSA incentive-based programs for farmers. Summaries of programs include overview of program goals, extent of implemented projects, GHG emission reductions estimates, administering state agency, and the allocated funding to the program to date. (Data from CalCAN Climate Smart Agriculture Programs & Climate Change Investments 2018 Annual Report) (California Air Resources Board, 2017b).

As shown in Table 2, programs focused on areas of agriculture from greenhouse gas reduction to conservation and water efficiency already exist in the state with significant funding. Regenerative approaches to agriculture can support all of these programs. The processing and application of manures back onto cropland retains nutrients and promotes soil fertility. No-till practices reduce the need for emission-intense machinery and as a result, reduce energy demand for farms. Healthier soils improve water retention, reducing the need for irrigation and increasing the efficiency of water use. Regenerative approaches inherently underscore all the initiatives

associated with Climate Smart Agriculture by striving to minimize impact and restore natural resources that have been deteriorated by historic agricultural practices.

Beyond existing policy, California's political climate aligns with regenerative goals as well, with demonstrated commitments to not just sustainability but also equity. In the aforementioned definition of regenerative agriculture proposed by a working group, one of the explicit target outcomes of applying this definition includes "Protecting spiritual and cultural traditions as well as supporting Native-led stewardship practices" (Cameron, 2025, p. 3). The state government is explicitly committed to justice and equity in all its practices, and extends this to the field of agriculture, with the California Department of Food and Agriculture establishing a Diversity, Equity, and Inclusion Committee in January of 2021 to acknowledge the problematic history of American agriculture and strive to make a more equitable future (*CDFA - OCR - DEI*, 2025). This too must be built into a regenerative transition, as part of the definition established for regenerative agriculture in this paper includes "managing simultaneously the indivisible complexity of human organizations, economy, and nature to sustain all businesses, economies, and civilization" (Cummins & Leu, 2024, p. 62). California thus possesses all of the necessary components for explicitly building out a regenerative agriculture framework through which to inform future agricultural policy.

The proposed next steps for the state are clear; expand upon the definition offered in January to the senator and incorporate it explicitly into state legislature, establishing a legal definition of regenerative that can then be used as part of a statewide initiative like the proposed STRAP. For California, this program could incorporate into itself existing initiatives like those in Table 2, organizing a working group or committee to find commonalities across these programs and establish financial incentives and technical assistance toward the goals of these initiatives

using regenerative practices. Further funding could be supplied through the introduction of a tax or fine for damage caused to the environment or natural resources as a direct result of less sustainable agricultural approaches. Inherent to this program would also be an emphasis on localizing supply chains, with government assistance offered to support infrastructure connecting producers more directly to consumers. This need not be limited to the state's borders, as a critical component of California's economy involves food exports, and the rest of the country and even the world has come to depend on these exports. Rather, over time this reliance could slowly be lessened through trade restrictions or economic instruments, encouraging other areas to shift toward local production wherever possible.

Even for a state like California, the regenerative transition will be a significant and complicated shift, and there are certain to be obstacles and challenges that occur along the way. However, given the political inclination of the state's government, existing commitments to improving sustainability in agriculture, and the ever-growing threat of climate-change induced disasters, there may be no other state better poised to guide this transition. As a national leader in food production, California has significant influence over both the food system and national agricultural policy, and if applied effectively, this leverage could launch a nationwide effort to incorporate regenerative principles into the agricultural sector.

4.4.2 Iowa

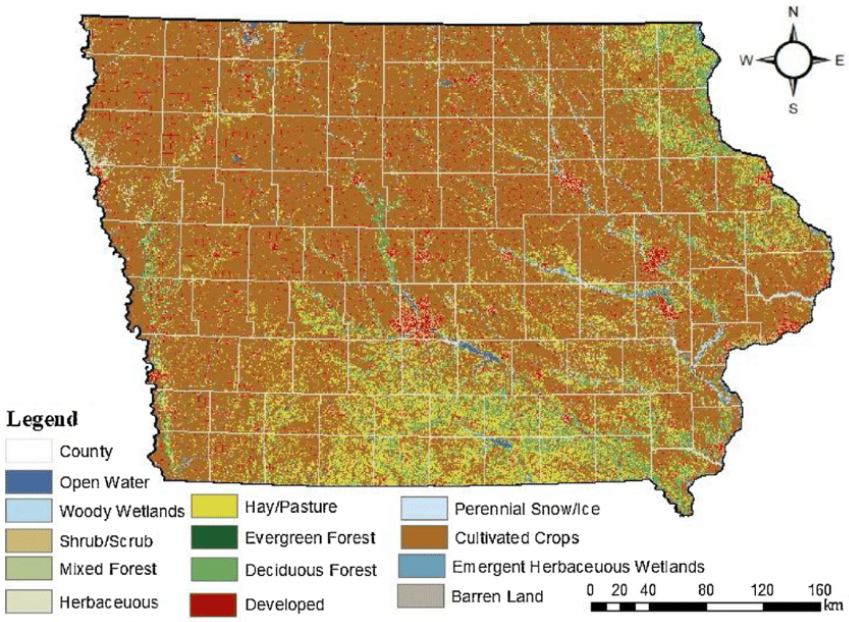


Figure 10. The location and land use map of Iowa, note the significant presence of cultivated crops and hay/pasture. Reprinted from "Developing Farmer Typologies to Inform Conservation Outreach in Agricultural Landscapes," by S. Upadhaya & J. G. Arbuckle Jr., 2020, *Land Use Policy, 101*, Article 105157 (https://doi.org/10.1016/j.landusepol.2020.105157). Copyright 2020 by Elsevier.

As established previously, Iowa possesses a distinctly different context from California in terms of agriculture. Despite being the second largest producer of crops in the nation, the vast majority of Iowa's agriculture (which, as shown in Figure 10 above, covers much of the state's area) is dedicated to corn and soybean production, making up more than 94% of total crop production, and leading the nation in corn production (ISU, 2023). A majority of this production isn't even used as food– at least not for human consumption. According to Mark Bittman, an American food journalist and author, "Fifty percent of the corn in Iowa is used to produce ethanol. Most of the rest goes to feed animals in confinement" (2019, para. 7-8). This in and of itself is not a problem; ethanol has been proposed as a renewable biofuel and an alternative to fossil fuels, and livestock need to be fed to accommodate meat demand and protein production in the country. However, the reality of Iowa's agriculture is that a majority is managed in ways that

are more consistent with historically industrial approaches than more sustainable regenerative alternatives.

Firstly, the extent of monoculture planting in the state runs counter to many of the principles of regenerative agriculture, even considering a rotation between the two major crops produced in the state. The predominant trend for Iowan farmers are "either an alternate-year rotation of soybean followed by corn (soybean-corn), one year of soybean followed by two years of corn (soybean-corncorn), or continuous corn" (Wright & Lenssen, 2013, p. 1), which in turn results in severe nutrient depletion in soils. While the alternation between corn and soy, which is a legume, contributes partially to regenerating nutrients like nitrogen, the lack of diversity in crops deteriorates soil over the years, leading to the application of synthetic fertilizers and pesticides. Tillage is also a common practice used on large swathes of Iowa's agricultural lands, which while helping to aerate soils and suppress weeds, further damages long-term soil health, including water infiltration (Wright & Lenssen, 2013).

The problem of water infiltration in agricultural soils is also tied to another major product of Iowa's industrial agricultural practices: runoff from fertilizers. Research from the Environmental Working Group assessed levels of nitrate and phosphorus drawn from over 10,000 public and community water monitors and systems in the Upper Mississippi region, which in addition to Iowa includes Illinois, Minnesota, and Wisconsin. This research revealed that the state is drowning in manure and commercial fertilizers, specifically localized to agricultural cropland; "80 percent of surface water monitors and 83 percent of groundwater monitors with elevated phosphorus levels of at least 100 micrograms per liter, or ug/L, were located in counties where more than 70 percent of cropland is fertilized" (Environmental Working Group, 2021, para. 5). This is troubling not just for the environment, where it regularly

results in algal blooms and eutrophication, but is also a major cause of concern for public health. The scope of this problem also extends far beyond the borders of the states, with runoff from into the Mississippi river making Iowa "the number one contributor to the Dead Zone in the Gulf of Mexico" according to the Great Plains Action Society, an indigenous advocacy group (Nobiss, 2021, para. 3). Addressing the consequences of this problem is also likely to be extremely costly, with estimates of over $5 billion in addition to legislation and legal action necessary to improve water quality (Beeman, 2021). A much more effective approach would act on the problem at its source: transforming agricultural practices.

Beyond the practices themself, there is also a cultural resistance in Iowa which further distinguishes it from the climate of California. A product of centuries of the "colonial-capitalist model" (Nobiss, 2021, para. 31), Iowa is deeply entrenched in the systems that produced industrial agriculture and have allowed it to become the dominant agricultural force in the state. Some theorists have argued that this has created a system which serves to perpetuate industrial practices, even among researchers. According to Silvia Secchi, a natural resources economist, "the spaces she inhabits are also largely dominated by white men with close industry connections, people who have a lot to lose if they alienate more powerful interests" (Fassler, 2021, para. 126). That more powerful interests can inhibit scientific research and progress, especially in the realm of protecting natural resources, emphasizes the systemic obstacles to reforming the American food system. This unwillingness to consider change is a major inhibitor of progress and stands in the way of a regenerative transition. As long as producers feel loyal to or incentivized to maintain industrial practices at the expense of environmental and public health, the process of building a regenerative future will be slowed.

Iowa shows some promise, though, and there exist several points around which to build momentum and steer agriculture practice and policy in a more sustainable direction. Cover-cropping and no till practices in particular show potential for growth in the corn capital of the country. In 2022, an estimated 1,282,608 acres of Iowa's agricultural land planted cover crops, an increase of 309,496 acres relative to 2017, making up more change than the neighboring Illinois and Indiana in that same time period (Plastina et al., 2024). Even more significant are trends in acreage under no-till practices, where in recent years "Iowa increased no-till usage by 256,262 acres between 2017 and 2022, bringing its total no-till area to 8,452,461 acres, equivalent to 32.7% of its cropland area" (Plastina et al., 2024, para. 6). These changes did not happen in a vacuum, but are rather a direct result of state incentives, including the Crop Insurance Discount Program discussed in section 4.3.2. Other existing initiatives include the Iowa Nutrient Reduction Strategy, a joint effort by Iowa State University, the Iowa Department of Agriculture and Land Stewardship, and the Iowa Department of Natural Resources (Iowa Nutrient Reduction Strategy, 2025). This program supports efforts to reduce runoff into waterways and improve the conditions driving the Dead Zone and hypoxia in the Gulf of Mexico. In addition to data monitoring and reporting, the strategy also involves working closely with farmers in the state to identify opportunities for reducing nutrients in surface water. Regenerative approaches like instituting cover crops and no till practices help improve soils, leading to a greater retention of water and a reduced need for synthetic fertilizers, thus representing a potential entry point for expanding regenerative approaches in the state.

Federal support will be instrumental in guiding a regenerative transition for the state; Iowan farmers are currently highly dependent on existing programs like the FCIP to continue to make profit through artificially high corn and soy prices. Additionally, encouraging a diversity of

crops and a gradual decrease in monoculture style production will require federal and state incentives for both financial and technical support as well as to overcome cultural resistance to new forms of food production. From the state level, establishing an agency dedicated to educating farmers on the science and benefits of regenerative practices like no till and cover cropping will be instrumental in shifting the focus of farmers from profit margins to environmental stewardship. The motivation to do so for the state extends beyond food production and into improving public health and natural resources, as demonstrated by existing programs to improve water quality and reduce agricultural runoff.

Finally, an economic instrument will also be a critical component to enable farmers to take on the initial burden of moving away from industrial agriculture. Research has demonstrated that incorporating organic and no till practices in Iowa applied to corn and soybean come close to the margins of a tillage approach, but remain at a slight deficit, suggesting that "soil improvements probably cannot offset the economic losses in no-tillage systems" (Delate et al., 2012, p. 49), with the authors proposing a consideration for the economic benefit of enhanced soil carbon to make up this difference (Oldfield et al., 2022). Incorporation of credits or other economic instruments recognizing the benefits of carbon sequestration from regenerative practices could accompany other federal and state initiatives to improve the economy of regenerative agriculture. Establishing a loan program to cover the initial drop in profits per acre that can then be paid back on a five to ten year timescale once the breakeven point has been reached (recall Figure 7) could also support this obstacle. Furthermore, introducing a slight interest rate on these "regenerative loans" could then generate additional funds to fund soil carbon credits or support educational programs and technical assistance to further motivate farmers to shift toward more sustainable agricultural practices.

4.5 Conclusion

The political landscape of agriculture is poised for a significant change. With national legislation like the Farm Bill and its numerous subsidiary programs, proposals to define the term regenerative agriculture to inform state policy, and a demonstrated interest in and need for reducing the environmental impact of farming from California to Iowa, a regenerative revolution is possible. Progress is not going to be constant, and different states are certain to emerge as leaders while others will require more involved lobbying, education, and federal support. Concretizing the term regenerative agriculture at the federal level is the fundamental first step, upon which programs like the proposed STRAP and RASP can be established and funded. Iterations of state-level initiatives specified to their political and ecological contexts will complement and interact with national policy as well as draw support from the private sector if they are to be successful. This is no small ask– it will require a fundamental rethinking of how the nation produces food. However, in the face of impending global warming and increased natural disasters from climate change, reforming agriculture is the only way to prevent it from becoming increasingly threatened. Furthermore, this is an opportunity for the country to make significant progress toward climate commitments and goals, potentially redefining a historic legacy of inconsistency in the international climate sphere and a history of benefitting at the expense of the planet. In achieving a successful regenerative revolution through policy, the United States could alter the trajectory of the entire future of the planet.

Conclusion

"*The ultimate goal of farming is not the growing of crops, but the cultivation and perfection of human beings*"[5]

Masanobu Fukuoka

Japanese farmer and philosopher

(1913–2008)

5.1 Introduction

This paper sets out to introduce the path toward a major overhaul of the American agricultural system. Both a return to environmental stewardship and indigenous practices and the breaking of new ground in terms of large-scale efforts toward regenerative agriculture, this revolution makes a historically significant ask of policy measures. It may seem unimaginable for such a change to be possible in today's fast-paced global society. However, it is not without precedent. The Green Revolution of the 20th century is widely acknowledged to have saved a billion lives by improving the global food supply and availability of nutrition. The Industrial Revolution saw booms in agricultural output, a scaling up of farm sizes, and a transformation in practices that had been in place for centuries to millennia. Before that, even, the Neolithic Revolution played a major role in allowing for the development of a more sedentary lifestyle, birthing cities, and spurring the development of a multitude of new cultures and ways of living. Taken in the broader context of the history of agriculture, global shifts in farming and food

[5](Fukuoka, 2009)

production have marked the milestones of human history. In the face of climate change, politicized access to critical supply chains, and a growing population with increasing expectations of more calories from higher up the food chain (Yates-Doerr, 2012), a fourth agricultural revolution is more than possible; it is critical.

Regenerative agriculture may itself be taken as a contentious solution, due to its ambiguity, a stark contrast to the conventions of industrial agriculture, and the political, economic, and environmental obstacles to its implementation in the U.S. Taken from the perspective of ecology, land management, conservation, and climate science, the benefits are clear and the proposed solutions are urgent. As with any proposed change in practice and policy, though, there are certain to be obstacles. The questions of feasibility, economics, and political viability are real and must be acknowledged and addressed. It is worth noting that these changes need not and will not be starting from ground zero. Existing frameworks and emerging policies and initiatives provide a basis upon which further action and scaling up can occur. The ever-shifting nature of the American political landscape may represent the largest barrier to a regenerative transition, and barring federal investment into sustainable agriculture, states and other actors may emerge as the driving force. Across significantly different contexts, progress is already occurring, from soil initiatives on the West Coast to better water regulation and management in the Corn Belt.

An effective approach to achieving a regenerative revolution will require the suggestions outlined in this investigation, as well as countless future iterations, adaptations, funding mechanisms, and further research. Beyond that, a successful, equitable, and sustainable transformation of the American food system will require dedicated interdisciplinary action to bridge historical, scientific, and political perspectives. The following section will synthesize

these three perspectives highlighted by each of the respective preceding chapters. Section 5.3 will trace out the implications of the suggestions and arguments presented in this investigation. Concerns and the most significant limitations will be raised and considered in section 5.4, and the final section will consider the question of a regenerative revolution in its totality, offering a cautiously optimistic perspective for the future of the American food system.

5.2 Synthesis

Chapter 1 introduced the history of American agriculture (as it is understood from the perspective of the Western nation), from its origins in the 15th century through to the complex and enmeshed international trade hub of today, churning out massive amounts of commodity crops through large-scale operations. While not exclusively the case, large-scale and industrial agricultural practices have become the norm, with small, local, and regenerative producers being a fairly small portion of the market. As demonstrated against key environmental criteria, the impacts of the current system of food production cannot not be ignored. From swathes of intensively managed land to major contributions to global GHG emissions to disruptions in natural water and nutrient cycles, the current system is able to function by skirting the environmental costs of operation and crop production.

As highlighted by the case study of the Dust Bowl, interactions between unsustainable farming practices and climate change can prove disastrous. In the face of severe climate projections and regularly halted and insufficient climate action, the situation is certain to worsen before it gets better in terms of severe weather events and climate variability. Industrial practices are flawed in both their role in contributing to climate change and their inability to be resilient, requiring huge volumes of additives, including pesticides, herbicides, and fertilizers which go on

to have trickle-down effects on broader natural ecosystems. Furthermore, the current system is highly dependent on human and capital input, in stark contrast to regenerative agriculture which, if properly executed, is much better able to stand on its own and adjust to a wider range of conditions. Regenerative agriculture, with its emphasis on interconnectivity and mutual benefits both to human civilization via food production and ecosystem services, and natural improvements across environmental criteria relative to industrial agriculture, represents a beacon of hope in the food system. Establishing its emphasis on interconnectivity and support for "the indivisible complexity of human organizations, economy, and nature to sustain all businesses, economies, and civilization" (Cummins & Leu, 2024, p. 62), regenerative approaches strive to go beyond sustainability to improve natural ecosystems and landscapes, restoring resources and the health of environments.

The scientific case for regenerative agriculture is made in Chapter 2, drawing on a range of studies from soil health research in the early 20th century to very recent economic analyses. Understanding the nuances and complexities of regenerative agriculture, including the challenge of expanding versus intensifying land use, its potential for restoring soil health and sequestering carbon, and for restoring natural resource cycles presents a full picture of the potential benefits of transitioning. Some of the specific practices encapsulated beneath the broad umbrella of regenerative approaches highlight tangible actions producers can take on their lands to shift to a more sustainable and restorative model. Equally important to take away from this chapter are some of the major challenges standing in the way of a regenerative revolution. Questions of scalability, economic profitability, and accessibility remain major sticking points in the wide-scale adoption of the approach into policy. Further complications arise when considering the history of agricultural policy in the US, which has traditionally served to uphold and maintain

profit- and yield-driven outcomes at the expense of the environment. Even so, the benefits seem to outweigh the costs, especially considering the scope of regenerative approaches which can range in scale and intensity, and can be tailored to local contexts.

Chapter 3 brings the problems of the past and the case for a more regenerative future into the field of policy, unpacking the current state of US agricultural legislation. Largely driven by the Farm Bill, existing agricultural policy contains entry points for change. Despite significant investment into keeping large-scale and industrial producers in business, there are a number of programs and initiatives at both the federal and state levels that support regenerative practices, and provide a basis upon which further action can be integrated. Working across scales, and incorporating private-sector actors and markets is demonstrated to be of the utmost importance for moving the needle forward at a reasonable pace and at an effective scale. Examining the current practices of two major agriculturally productive states, California and Iowa, demonstrates that there is potential for regenerative agriculture to take hold across drastically different political, ecological, and cultural landscapes while still remaining inherently tied to the unique conditions of their respective regions. The chapter closes with a call to action and push for the US to take action, both for the security and health of the planet, and to place itself as a global leader in the movement to improve global food system sustainability.

5.3 Implications

The implications of this proposal are significant, although realistically outcomes should be expected to play out gradually should regenerative agriculture gain more of a foothold and continue to expand across the nation's farms and production facilities. This is not cause for concern, but rather careful consideration. Attempting to predict every impact of a regenerative

transition from the most minute to the global scale is neither realistic nor worthwhile. However, identifying the key areas in which regenerative agriculture can be expected to make the largest change is a worthy undertaking. Firstly, consideration must be given to the environmental benefits, which are the fundamental basis for crafting this argument. Further attention should be directed to the economic and agricultural viability of this proposal, especially if significant changes are made from which recovery may be slow or severely challenging. Lastly, if a regenerative transition is to take place, it is certain to both cause and be impacted by social and cultural shifts in behaviors and attitudes toward food production.

As established in the second chapter, the environmental benefits make the strongest case for regenerative agriculture. Reduction in greenhouse gas emissions through soil carbon sequestration could markedly reduce the contribution of the US to global atmospheric carbon dioxide concentrations. This in turn could transform the nature of international climate negotiations and action as regenerative agriculture is allowed the opportunity to prove itself to a global audience. International carbon markets could arise around these practices, and the attention of climate scientists and activists could be drawn toward the agricultural sector as a promising area for action. This would in turn free up resources and funds for research and action to some of the other major sectoral contributors to climate change, supporting changes like a clean energy transition and reduction of reliance on fossil fuels. Further environmental benefits like improved soil health and resilience will be critical in the face of climate change. Increased resiliency may prove to be one of the most significant impacts of a regenerative revolution, and could protect agricultural lands across the country from significant potential losses, further building a case for the adoption of regenerative approaches. Lastly, regenerative agriculture offers a source of hope for smaller farmers and producers, who are likely to be disproportionately

affected by the impacts of the climate crisis barring the proposed federal and political interventions. Without making progress toward such a transition, the coming decades could see the complete end of the small farmer and further establish a nation- and market-wide dependency on large-scale, industrialized, and federally subsidized agricultural operations.

In addition to the implications of the environmental benefits of a regenerative revolution, the economic and agricultural viability of the proposed policy changes must also be considered. The economic viability of this proposal is at best tentatively promising and at worst potentially damning. However, with the policy and economic instruments proposed in the third chapter, regenerative producers could actually see increased long-term farm profitability, partially through improved yields and perhaps more significantly (at least up front) through reduced input costs. These costs would transform the agricultural market in the US if effectively applied at a national level, and could contribute to the American economy by allowing for greater exports and profits from the food sector. Beyond the strict economics, a regenerative agriculture transition could be further viable through more distal positive impacts on public health and food security by stabilizing soil productivity and reducing reliance on external inputs, creating a more consistent output and reducing the costs associated with presently externalized environmental costs. Lastly, economic improvements to this transition could come from the creation of new and emerging market opportunities for regenerative products as well as the potential for new economic incentives like the aforementioned carbon market or even ecosystem service payments if effectively quantified at national standards.

Finally, one of the most interesting and least discussed implications of a regenerative transition will be examining the social and cultural shifts that are both necessary for and will result from making these policy changes. Fundamentally, one can expect a reconnecting of

farmers with sustainable land stewardship traditions, including Indigenous agricultural knowledge. This could be both a potential form of honoring and respecting marginalized communities, allowing Indigenous scholars and stakeholders to act as experts and leaders, and as a potential source of resistance from more traditional and conservative farmers, who may reject alternative perspectives. Careful attention should be paid to maintaining positive relations in these transitions while emphasizing respect for the indigenous practices and histories from which many of these regenerative practices have emerged. It could also mark a potential area for significant growth in improving effective environmental, land, and resource stewardship, cultivating a culture that is more aware and protective of the environment. Additional social shifts are likely to take place in rural economies, which may be expected to expand and shift by promoting diversified farming systems, creating more robust markets that can serve a wider range of purposes and appeal to wider audiences. It remains to be seen what the role of consumer awareness and demand will be in driving forward these policy and market changes, and only time will tell where the sentiment of public favor will fall.

5.4 Concerns and Limitations

Before concluding this discussion, it is imperative to explicitly outline the largest concerns and limitations that stand in the way of making this regenerative transition. Economic and structural barriers will pose some of the most significant challenges up front, as farmers are hesitant to take on risks associated with making changes to their practices and methods of production. The continued demand for natural resources, including land and water will continue to complicate the development of a sustainable food system. Scientific and practical challenges will also represent an issue wherever regenerative approaches are applied according to

hyperspecific local and regional contexts with distinct demands from food producers. Finally, policy and institutional constraints are some of the most established that could emerge to stand in the way of a regenerative transition.

As highlighted in section 3.5, the question of economics is significant in inhibiting the expansion of regenerative practices and approaches, especially for farms already established and supported by industrial practices. Aside from the behavioral transition necessary to convince producers to change their practices, there are costs associated with transitioning away from mainstream practices toward more regenerative strategies. Farmers as a whole tend to be fairly risk-averse (Iyer et al., 2020), especially in making changes that could reduce yields and profits needed to support their livelihoods. Even with some of the economic instruments proposed in Chapter 3, many food producers are simply not in a position to take on the initial costs needed to make changes to their operations that take years to prove profitable. Incentives will need to be sufficiently compelling to create interest, and support and technical assistance will be critical to encouraging this group to bear potentially high transition costs and financial risks. The situation is further complicated by the dependence of many producers on federal subsidies that favor the practices associated with industrial agriculture. Dismantling this structural obstacle will be slow, and could inhibit action attempted at subnational levels. Finally, even if some of the suggestions posited in the final chapter are implemented, like carbon markets and ecosystem service valuation, these methods of addressing externalities are somewhat novel and experimental and thus create further uncertainty, both for farmers and for outcomes that could prove detrimental to a regenerative transition.

Beyond these obstacles, there needs to be pronounced progress in both scientific research and regenerative practices to better understand their ability to improve environmental outcomes.

For example, a long-term national study of the difference for farms in different geographical, climatic, and political contexts before and after transitioning to regenerative agriculture would prove critical to advancing federal or state initiatives like RASP and STRAP to promote these practices. As of yet, this study does not exist, and so there remains uncertainty and room for criticism of a regenerative transition. This is reflected by the reality that there is fundamental variability in outcomes depending on regional conditions and farm-specific practices. While this is not inherently unique to regenerative producers, it is a legitimate cause for concern for both farmers and policymakers across scales, and requires investigation to strengthen the case for transitioning out of current practices. Lastly, understanding and overcoming trade-offs will require detailed review and research into the practices associated with regenerative agriculture. For example, in association with the economic concern, there is a risk of short-term yield declines during the transition, which although these may be offset by reduced spending on chemical inputs, the long-term payout is not clear for all producers. Similarly, potential increased labor demands do not fit neatly into the proposal offered and could prove consequential if not adequately considered and addressed.

Finally, policy and institutional constraints could prove to be the biggest hurdle for regenerative advocates. Major corporations involved in the global food system are deeply entrenched in maintaining current practices to keep profits high, costs low, and to externalize the burden of environmental impacts on other parties. These entities hold significant sway across every step of the food system (Perry Stillerman, 2024), and make significant contributions and efforts to lobby politicians and hold sway over officials to ensure policies are aligned with their practices, motivated by maintaining their bottom lines. In stark contrast to this concern, there is also a worry that the opposite problem may take place, where large-scale industrial producers

take up the regenerative banner and effectively re-engineer the term, simultaneously diluting a promising solution and greenwashing practices. This form of misleading audiences by selectively presenting branding that emphasizes value-aligned actions without demonstrating follow-through in actual practices is a common frustration in the environmental arena, and is prevalent in the food industry (Nugraha et al., 2024). Without careful marketing regulations and stronger consumer awareness of what regenerative means, this transition could quickly be extorted and transformed to serve current players.

The complexity of implementing large-scale policy reforms is also one of the most glaring limitations of this proposal. At its heart, it is inherently aspirational. While feasible if applied gradually and with an emphasis on adaptability as more information becomes available and different regions make progress on a regenerative conversion, it will be a remarkable undertaking to achieve these policy changes. Furthermore, under the rapidly developing and changing landscape of the Trump administration, it is challenging to make definitive claims or predictions for what proposals are likely to be considered and accepted. As is evident to actors in the realm of food and agriculture, the state of agriculture and federal agricultural policy for the next four years is currently unclear. Farmers are already struggling to make sense of how to adapt in the face of freezes on spending and the loss of federal funding needed (Heller, 2025). However, Robert F. Kennedy Jr.'s recent swearing-in as the nation's health secretary could potentially prove beneficial for a regenerative transformation. As an outspoken proponent of regenerative practices and soil health (Davies & Alvey, 2025), his influence in the administration could prove critical for moving the needle forward on dismantling some of the most harmful practices associated with industrial agriculture. Only time will tell what the future holds for American agriculture policy, and it is entirely possible that the proposals set forth in Chapter 3

will not be realized under the current administration. The sharp polarization of the American government and the politicization of climate action as a progressive and partisan issue will be especially relevant to changes in the agricultural sector, largely upheld by rural and conservative stakeholders. Bridging this gap with regenerative agriculture would be a landmark in bipartisan cooperation, and it is at present murky when the nation may be able to achieve such an undertaking.

5.5 Conclusion

The American food system is a massive, complex, and unwieldy institution. Critical and political, highly productive and environmentally threatening, simultaneously local and global. International attention is increasingly casting its eye on food policy and production, in the face of threats to food security, disrupted supply chains, and the uncertainty surrounding the planet's future climate. Calls have gone out from some of the world's foremost leaders, seeking an answer to amend the threats both posed by and facing food production for the world's populations (World Food Prize Foundation, 2025). The transition to regenerative agriculture represents both a return to sustainable land stewardship and care for (rather than extraction of) natural resources, as well as an innovative path forward in agricultural policy.

A successful regenerative revolution serves to address some of the most urgent and pressing issues facing society today. By both reducing contributions to GHG from agriculture and acting as a carbon sink through the gradual sequestration of organic carbon in soils, regenerative practices represent a form of agriculture that will be of increasing importance as global temperatures continue to trend upwards. Changing the composition of fields to incorporate a mixture of crops and varied management practices are also likely to promote

improvements in biodiversity and threats to species, presently driven by land use for agriculture. Less acknowledged but of special importance for food production and future sustainability of agriculture is the issue of soil degradation, which is one of the primary focuses of regenerative management. More broadly, regenerative approaches function inherently more holistically to improve not just ecological outcomes, but also to support human livelihoods, emphasizing interconnectivity and a focus on local supply chains, more sustainable than the global exchange of food items.

While the proposal outlined in this discussion is focused primarily on utilizing public policy to promote this revolution, other arenas are critical to the success of this mission. Just as regenerative agriculture is inherently interconnected, the pathway to a regenerative transition must be interdisciplinary. Policymakers will play a major role in laying out the groundwork for the actual realized adoption and transformation of the American food system. However, the solutions posited by these policies require robust and rigorous scientific research and backing. Furthermore, farmers will be the hands and feet of this shift, with literal hands in the soil acting as the base of a new, regenerative food chain. On the opposite end, consumers will also play a huge part in making this a successful transformation, especially in shifting the market and influencing the private sector. There is valuable influence in the purchasing power of consumers when taken collectively to shift the practices of larger corporations and distributors. The private sector, with sufficient pressure from legislators, regulators, and consumers combined, will also be driven to take up regenerative products and their corresponding regulatory requirements, assuming effective communication and legislation to define and verify the term.

The challenges facing this regenerative revolution are significant and complex. As mentioned, though, changes of this scale are not without precedent, with the designation of the

Fourth Agricultural Revolution serving as a reminder that such wide scale transformation is possible. With the proper combination of environmental pressure, policy stimuli, scientific evidence, and scientific will, reform is possible. While the present state and short-term future of agriculture is uncertain, latent to a regenerative approach is a forward-looking perspective. Proper execution of this change will transform not just the American food system, but will have trickle-down effects across sectors and nations. By implementing the proposals laid out in this paper, achieving a regenerative agriculture revolution can act as the foundation for a resilient, equitable, and sustainable food system and as a model for global change for future generations to come.

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Appendix A: Letter to Secretary Ross on Defining Regenerative Agriculture

Recommendation from the California State Board of Food and Agriculture to CDFA Secretary
January 2025

Defining Regenerative Agriculture for State Policies and Programs

"Regenerative agriculture," as defined for use by State of California policies and programs, is an integrated approach to farming and ranching rooted in principles of soil health, biodiversity and ecosystem resiliency leading to improved targeted outcomes.

Regenerative agriculture is not an endpoint, but a continuous implementation of practices that over time minimize inputs and environmental impacts and further enhances the ecosystem while maintaining or improving productivity, economic contributions and community benefits. "Regenerative agriculture" is an ongoing continuum of sustainability for California's farmers and ranchers, informed by current science as well as the traditions and innovations from the original Indigenous stewards of the land.

Examples of target outcomes include:

a) Building soil health, soil organic matter and biodiversity. (Healthy Soils Program); (AB 1757)

b) Increasing statewide implementation of conservation practices that improve soil health, sequester carbon and reduce greenhouse gases; (USDA NRCS Conservation Practice Standards)

c) Furthering sustainable pest and integrated pest management to reduce the reliance on pesticides; (Accelerating Sustainable Pest Management: A Roadmap for California) ;(UC Statewide Integrated Pest Management), (USDA NRCS pest management conservation system)

d) Protecting the welfare and care of animals in agriculture; (Animal Care Program)

e) Building healthy, local communities; (Ag Vision)

f) Protecting spiritual and cultural traditions as well as supporting Native-led stewardship practices;

g) Minimizing negative impacts to other target outcomes;

h) Maintaining positive impact on the economic vitality/livelihoods of farmers and ranchers.

Regenerative agriculture will require processes, practices, monitoring, evaluation, and innovation to be customized to specific production systems, ecoregions, and local Indigenous cultural regions. Practice selection is based on the best available science and

practice, including but not limited to, organic and traditional ecological knowledge, for production systems.

This recommendation is to inform State Agencies, Boards and Commissions on CDFA's definition of regenerative agriculture as it relates to state policies and programs. This is not a definition for certification.