Restoration Through Regeneration: a Scientific and Political Lens into Regenerative Agriculture in the United States

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Executive Summary: The current agricultural system in the U.S., commonly referred to as industrial agriculture, is a system where the main goal is to produce the highest possible yield of crops at the lowest cost, for both human and livestock consumption, and relies heavily on manipulation of the land with monocropping, tillage, synthetic pesticides, and fertilizers. These practices compromise biodiversity, soil health, ecosystem health, and ultimately human health. It is becoming increasingly clear that we cannot sustain conventional practices if we wish to provide a healthy food system to future generations. An alternative, known as regenerative agriculture, produces high yields while also building soil health, increasing biodiversity, improving water cycles, and sequestering carbon. To achieve these goals regenerative agriculture utilizes a core set of techniques which include no-till farming, cover cropping, increased crop diversity, integration of livestock, and the reduction or elimination of synthetic pesticides and fertilizers. Such practices have been shown to be more productive in the long term and more resilient when faced with severe weather events. Currently, there is a need for policies to help farmers implement regenerative agriculture principles, but conventional agriculture has become both politically and economically embedded in the U.S. food system. Not only do our current policies fail to adequately assist regenerative agriculture systems, they also actively support conventional agriculture through, for example, subsidy programs. This document serves as a comprehensive overview of the scientific understanding of agriculture, history of U.S. agricultural policy, key stakeholders in the field, and policy recommendations to expand regenerative agriculture.

I. Scientific Background

Agriculture is the science of growing crops and raising livestock as a reliable source of food for everyday consumption. It encompasses a wide variety of factors: the structure and chemistry of the soil, the biodiversity of plants and animals that are parts of the farm and the ecosystem, and the response of plants to climate change. In this science background, we discuss the basic concepts surrounding agriculture to better understand its effect on our health and our environment. We focus on basic soil biology and chemistry to illustrate the

various factors that influence soil health and crop success. We also cover the importance of biodiversity and the negative impacts of monocropping on wildlife and the environment. Lastly, we cover the science behind chemical pesticides and fertilizers, as well as their negative impacts on the nutritional quality of the crops and human health.

i. *Role of soil health in farming*

Basic soil biology

Soils are made up of four components: minerals, gases, water, and organic matter. Minerals make up as much as 45% of soils' contents and have been created through billions of years of weathering rock (Nathan 2017). Soil minerals are either sand, silt, or clay. Sand makes up the largest particles found in soils, silt are medium sized particles, and clay particles are the smallest particles.

Gases account for around 25% of soil's content (Nathan 2017), and three specific gases are key ingredients that promote the health of plants as well as the microorganisms that live within the soil. Carbon dioxide is essential in soils to assist in photosynthesis, nitrogen gas is necessary for plants to build proteins, and oxygen is integral for the survival of insects and microorganisms in soils. Water can make up approximately 25% of healthy soil content (Nathan 2017). Water is a solvent which allows soil nutrients to flow throughout a plant's structure. Water is essential for the survival of all animals and plants and without it neither can successfully continue their natural processes.

Soil organic matter (SOM) can make up 3-5% of soil content depending on the soil quality (Nathan 2017). SOM includes both decomposing and living organisms such as bacteria, algae, fungal spores, fungal filaments (ie. mycorrhizas), earthworms, and exoskeletal insects. SOM is a key indicator of healthy soils. The higher the SOM content, the richer the nutrient make-up of the soil. Living microorganisms break down the dead and decaying SOM by consuming and expelling it into an accessible source of nutrients for plant intake. Without this cycle of death and rebirth into the soil ecosystem, the natural nutrient cycles will cease to function in those soils.

Soils are organized in layers or horizons dependent on depth from the surface. The topmost layer, or surface layer, is considered 'horizon 0'. This layer is made up of humus (pure SOM) mixed with partially decomposed plant debris. Topsoil is the second layer or 'horizon A'. The percentages of soil content given above describe the components of topsoil. The third layer is called the zone of leaching because beyond the topsoil layer, nutrient-holding capacity dwindles and thus nutrients get washed out of the roots' reach. Subsoil is found in the fourth layer, primarily composed of slightly heavier and larger minerals. The fifth layer is the parent material, which is the substance from which soil develops, and the sixth layer is bedrock.

Soil chemistry

Soil's chemical properties are dependent on its pH level, which affects the availability of nutrients to plants as well as the population diversity and activity of microorganisms. Nutrient availability is key for successful plant growth, from early development stages to maturation. Primary nutrients include phosphorus, nitrogen, and potassium. Phosphorus is essential for forming nucleic acids, such DNA and RNA, and to store or transfer energy. Nitrogen is key for building plant proteins. Potassium is integral for transporting sugars and forming starch within plants. Secondary nutrients include calcium, manganese, and sulfur. Plant growth is also reliant on the intake of micronutrients such as boron, chlorine, copper, iron, nickel, and zinc. For successful growth and fruit production, all nutrients mentioned above must be present in biologically usable forms and in certain quantities.

Soil tillage and its effects on soil health

Soil tillage has been deemed as an essential farming practice for the success of plant growth and production by modern and conventional agricultural traditions. Tillage is the action of turning or mixing the topsoil layer. Soil tillage is used to rid the surface layer of crop residue after a harvest as well as to prepare a seedbed before planting by softening the soil, with the additional benefit of killing all

undesired weeds. This practice minimizes human labor used upon the field by using animal or machine-pulled tools. However, the impacts of tillage practices are not exclusively beneficial. Several disadvantages have become apparent through history, farmer experience, and scientific research. The mixing of soils disrupts SOM ecosystems, releases stored carbon dioxide into the atmosphere, increases soil erosion, decreases soil moisture, increases topsoil loss, and intensifies soil compaction due to its continuous use of heavy machinery (Nathan 2017). Although modern cultures have supported the use of tillage, indigenous groups have understood the long-term benefits of farming without the use of tillage for centuries.

No-till is the practice of not turning a field's soils, and instead using other methods such as seasonal crop rotation, cover cropping, and crop diversification. One principal aspect of no-till is that there is never exposed soil on any field, which increases resilience against soil erosion. In comparison to tilling, no-till improves soil fertility, root and microorganism interactions, drainage, and water filtration (Nathan 2017). Some global scale meta-analysis studies indicate that 1) "no-tillage improves soil properties, increases soil bacterial community diversity, and changes the relative abundance of some dominant bacterial phyla" (Li 2020) and 2) "switching from MP (moldboard plow) to NT (no-till) increased SOC (soil organic carbon) content, measures of biological activity, and labile C and N fractions of SOM in the topsoil while also improving biological soil function at deeper soil depths" (Nunes 2020), and 3) "microbial biomass and enzyme activities, in general, are greater under no-till than under tillage" (Zuber and Villamil 2016).

ii. Role of biodiversity in farming

Modern farming practices have completely changed the earth's natural landscapes by clearing huge expanses of land and significantly reducing the biodiversity on those plots. For context, "the world's agricultural landscapes are planted mostly with some twelve species of grain crops, twenty-three vegetable crop species, and about thirty-five fruit and nut crop species… i.e., no more than seventy plant species spread over approximately 1,440 million [hectares] of presently cultivated land in the world, a sharp contrast with the diversity of plant species found within one ha of a tropical rainforest, which typically contains over 100 species of trees'' (Altieri 1999). Maintaining agrobiodiversity is critical for productive farming in that it protects crops from susceptibility to wipeout by pests, diseases, and climate fluctuations. It also preserves genetic diversity for the breeding of future crops for human use and promotes natural upkeep of soil health through decomposition of organic materials into useful nutrients and maintenance of healthy soil structure. A correct biodiversification of crops through a variety of methods can improve natural pest resistance and result in sustainable crop yields that require fewer artificial inputs.

Susceptibility of crops due to monocropping

Monocropping is the practice of planting the same crops on the same plots of land year after year with no crop rotation or land resting periods. One of the major concerns regarding the use of monocropping is the highly increased susceptibility of crops to wipeout. In the US, maize, soy, and wheat are three of the most widespread monocrops. These crops are planted in very close proximity and the plots are densely populated. The plants are essentially "standing like soldiers," which creates an opportune breeding ground for invading pests or pathogens that attack the specific species to spread quickly (Thrupp 2000). Because of this significant vulnerability to attack, farmers must rely heavily on pesticides. Furthermore, the same applies for climate disasters. The dependence on crops that require the same environmental conditions allows for very little resiliency in monocropping systems.

Pollinator preservation

It is widely believed that destroying wild plots (a planted area set aside to serve as food for wildlife) near farms will prevent attacks by pests. However, this can cause more harm than good because "biological control agents", such as birds and wasps that can prey on pest insects, often live in these nearby undisturbed areas (Hillel and Rosenzweig 2005). Birds and other naturally occurring organisms, such as insects, living in these wild plots

serve as crucial pollinators as well. According to work published in the *Annals of Botany*, "over 80% of the 264 species grown as crops in the European Union are dependent on insect pollination." The yields of fruit, vegetables, and legume plants are all "optimized by regular pollination" (Richards 2001). While this is perhaps less important in monocropping, it is a prime example of the ways in which a diversified crop structure could be more sustainable while requiring less external input.

The issues of the loss of natural pests are directly relevant to monocropping in that they have forced farmers to fall into the "pesticide treadmill" (Thrupp 2000). This is the idea that because of the lack of natural pest control and the high vulnerability due to the uniformity of crops, farmers rely heavily on pesticides every season. This inevitably leads to pest mutation and pesticide resistance development, thereby forcing farmers to rely on new pesticides and treat more aggressively with each coming season (see section 1.3). This, in turn, harms beneficial insects and fungi in the soil and on the plants themselves, further lowering the natural protections afforded by the environment, increasing the crops' susceptibility, and creating a cycle of pesticide dependence. This can create loss of productivity and certainly threaten the sustainability of the crop yields.

Maintenance of soil health

Biodiversity also plays a key role in the maintenance of soil health. Fertile soil is a major factor in establishing high and reliable yields and the soil's composition determines if external additives like fertilizer are needed. Soils rich with natural microorganisms require fewer external inputs because of the functions performed by the microorganisms, such as fungi, bacteria, actinomycetes, and animals, which include nematodes, mites, collembola, diplopodia, earthworms and arthropods. Some of the key roles they perform to maintain soil health and nurture crops include the decomposition of litter and cycling of nutrients, conversion of atmospheric nitrogen into organic nitrogen, suppression of soil-borne pathogens, enzyme synthesis, regulation of allelochemicals, and "interacting with plants through mutualism, commensalisms, competition, and pathogenesis" (Altieri 1999).

Carbon and nitrogen cycling are some of the most important functions of soils, and practices that include fibrous rooted crop rotations (such as legumes) increase the C and N inputs, which have been shown to have greater effects on increasing microbial populations than artificial fertilizers. The use of animal manure as natural fertilizer has also been shown to increase soil biota abundance. According to Altieri, "microbial and protozoan activity is highest in organically fertilized agricultural soils" (Altieri 1999). Pesticides kill many of these naturally occurring, vital microorganisms, causing farmers to rely on outside inputs to sustain growth. Revitalizing this biodiverse richness of soil is no easy feat. Monocropping practices also drain soil fertility because the growth of so many of the same species on the same plots of land depletes the soil of specific nutrients. Intercropping, or interspersing several rows of alternating crops rather than filling entire plots with the same crop, encourages efficient land use while maintaining diverse nutrient utilization.

Maintenance of soil structure

Biodiversity also plays a key role in the maintenance of soil structure. Interspersing trees and shrubs within agricultural plots can help to prevent erosion and strengthen the soil structure by contributing to a larger rhizosphere, which is the region of soil whose biochemistry is influenced by the growth and nutrient exchange of plants' roots. This soil structure is important because it allows microorganisms to live in denser populations, thus promoting the growth of the crops themselves. Tilling destroys the structure in the top 15-20 cm of soil, thereby limiting microorganism growth and reducing potential crop yield. The presence of worms in the soil, which can also be depleted through pesticide use, can be greatly beneficial because their tunneling creates room for aeration and water retention in the soil. Cover cropping, which involves planting various plants during a "rest period" on plots which are not meant to be harvested, is a sustainable technique that allows for the deposition of soil organic matter,

which can contribute to increased soil fertility by providing organic material to be processed.

iii. Use of chemical and natural fertilizers and pesticides

Regenerative agriculture emphasizes limited external inputs, including synthetic fertilizers and pesticides, to improve soil health, sequester carbon, increase biodiversity, improve water resources, and improve wellbeing of communities (Newton 2020), whereas conventional agriculture uses synthetic fertilizers and pesticides to achieve higher crop yields. However, this trend has resulted in negative consequences that threaten ecosystems, increase environmental and soil contamination, and reduce soil fertility. Therefore, alternative practices must be adopted to promote long-term access to safe food.

Why are fertilizers needed?

Nitrogen is an essential nutrient for life and nitrogen intake is needed for plant growth. Atmospheric nitrogen is the major source but it is not bioavailable to plants, so they must acquire nitrogen by absorption from the soil in two forms: nitrate and ammonium (Bhattacharyya 2020). In nature, it is the responsibility of the microbes in the soil to convert atmospheric nitrogen to the two bioactive forms through a process called biological nitrogen fixation followed by nitrification (Bhattacharyya 2020). Nitrogen fertilizer in the form of ammonia has been employed to enhance plant growth in agriculture and between 1960 and 1995 global use of nitrogen fertilizer has increased sevenfold (Tilman 2002).

Unfortunately, a significant amount of the nitrogen applied to crops is lost since only 30-50% is taken up by crops (Tilman 2002). The problem with this inefficiency is that the excess nitrogen ends up as runoff or is lost to the atmosphere. Runoff into local water systems causes eutrophication and low-oxygen conditions in nearby and distant ecosystems that kill aquatic life (Tilman 2002). The excess nutrients in water systems also causes algal blooms, which produce toxins harmful to wildlife and humans. Furthermore, nitrogen oxides emitted into the atmosphere increase tropospheric ozone, which is a component of smog, negatively impacting ecosystems and human health (Tilman 2002). Nitrogen also contributes to emissions of nitrous oxide, a potent greenhouse gas which has 300 times the global warming potential than CO_2 (Calabi-Floody 2018; Tilman 2002). In addition, the long-term use of these fertilizers has led to soil nutrient depletion, accelerated acidification, and organic matter loss (Calabi-Floody 2018). Phosphorus is another key nutrient that is not readily available to plants, and phosphorus solubility decreases in acidic soils. Depletion of soil nutrient content reduces the capacity of the microbes in the soil to synthesize and present these necessary nutrients to the plants. Without them, increasing amounts of synthetic fertilizer will be needed (Calabi-Floody 2018).

Adoption of specific agricultural practices such as soil testing and improved fertilizer application have been shown to help improve nitrogen efficiency and lower environmental loss (Tilman 2002). Furthermore, regenerative practices of cover crops, reduced tillage, intercropping, agroforestry, and buffer zones along water systems have been shown to reduce leaching of nutrients into neighboring ecosystems, may reduce erosion, and store carbon (Tilman 2002). Another idea for increasing efficiency of phosphate and nitrogen is the use of the microorganisms naturally present in soil (Calabi-Floody 2018). PGPR, a group of bacteria in soil, regulates key nutrient bioavailability to plants, through phosphorus and nitrogen fixation, and these bacteria have been proposed as an alternative to conventional fertilizers (Calabi-Floody 2018). Regenerative agriculture practices which focus on improving soil health will consequently promote healthy soil microbes.

Why are pesticides needed?

In addition to fertilizers, the use of chemical pesticides in US agriculture is widespread due to the argued benefit of improving crop yield and preventing food spoilage. Pesticides are products made of several chemicals, with the active ingredient attacking unwanted pests, including fungicides, herbicides, insecticides, and rodenticides (Freedman 2018). The use of inorganic or synthetic agents for pesticidal use became widespread in the early 20th century and rapidly grew thereafter. The number of

registered herbicides tripled between 1950 and 1969 and the use of all pesticides has increased tenfold in North America from 1945-1989 before leveling off (Council 2000; Freedman 2018). Public concern began to grow in the late 1950s over the potential dangers of synthetic pesticide usage (Council 2000). Since then, studies have revealed many detrimental effects of pesticides on the environment and human health.

One of the most significant impacts of pesticide usage in agriculture is the practice of non-specificity which causes ecological damage by killing non-target organisms. For example, non-target plants which provide habitat or food for animals can be affected, leading to unintended consequences throughout an entire ecosystem. Furthermore, pesticides can accumulate through the food web and indirectly expose non-target organisms (Freedman 2018). Like fertilizers, these pesticides used in agriculture end up making their way into water systems. Most pesticides do not biodegrade and cannot be removed from drinking water with standard purification methods. The mixture of pesticides found in water systems can be more dangerous than a single pesticide alone. Pesticides do not only affect nearby communities; through the hydrological cycle, they can evaporate, absorb into soil, wash into rivers, and be transported long distances (Freedman 2018).

One of the main concerns with transitioning to lower pesticide use is decreased productivity. However, a recent meta-analysis demonstrated that low pesticide use rarely decreases the productivity or profitability of farms (Lechenet 2017). Given the environmental detriment of pesticides, failure to decrease usage is not a viable option for the future.

iv. Effects of conventional farming on human health

The use of synthetic pesticides and fertilizers not only pose a serious risk for soil health and wildlife, but harm to human health too. In the human body, pesticides present in food may be metabolized, excreted or accumulated in body fat over time, and prolonged or intense exposure may lead to serious health conditions and death (Nicolopoulou-Stamati 2016). Pesticides may be involved in the development of cancers as well as endocrine, respiratory, reproductive, and developmental gastrointestinal disorders, and may be linked to neurodegenerative diseases such as Parkinson's and Alzheimer's (Xiao 2021). The main mechanism through which pesticides harm the body is by disrupting cellular homeostasis, either by increasing oxidative stress through the production of reactive oxygen species, or by unbalancing ion channels and neurotransmitters naturally present in cells (Mostafalou and Abdollahi 2013). Even though the exposure or consumption of pesticides through the food that we eat can cause a variety of diseases, we will focus on their role in neurodegenerative disorders, cancer and fertility,

Neurodegenerative disorders

Pesticides such as Rotenone, Paraquat, and Maneb have been found to increase the risk of suffering from Parkinson's disease (PD) and other dementias (Xiao 2021). There are several mechanisms through which they interfere with normal cerebral homeostasis. Rotenone can cross the blood-brain barrier (BBB) and combine with dopamine neurons, accumulating in the mitochondrial complex I in cells and causing oxidative stress (Xiao 2021). It has been widely used as a Parkinson-inducing drug in rats, since it induces alpha-synuclein aggregation in dopamine neurons, similar to Lewy bodies found in PD (Johnson and Bobrovskaya 2015). In a similar fashion, Paraquat can also enter the BBB and cause oxidative stress, promoting neuroinflammation and leading to exacerbated levels of inflammatory cytokines such as IL-6, which contribute to the process of dopamine neurodegeneration and development of PD (Berry 2010). The evidence that links Maneb to PD is more disputed, however, several studies have found that in combination with paraquat, Maneb will induce neurotoxicity via a synergistic effect through NADPH-oxidase mediated microglial activation (Hou 2017).

Cancer

Several studies have documented the role of pesticides in several types of cancer. There is data linking pesticides to lung, cervical, prostate, brain, pancreatic, kidney, stomach, pharyngeal, liver, mouth, ovarian, testicular, uterine, and cervical cancer, among many others. These chemicals can act

through various molecular mechanisms which alter the genetic material of the exposed individual. These changes can be heritable, thus leading to the appearance of early cancers such as leukemia (Mostafalou and Abdollahi 2013).

Fertility and developmental disorders

Several studies have documented a detrimental effect of pesticides in the reproductive health of males and females. The most common effects registered include decreased fertility, spontaneous abortion, low sperm count, altered sex ratio, birth defects, and fetal growth retardation. Furthermore, pesticide traces can be found in breast milk and can be transmitted onto infants through breastfeeding (Frazier 2007; Mostafalou and Abdollahi 2013). Organochlorine pesticides have been identified as endocrine disrupting chemicals, which are a key component of alterations in the endocrine system and metabolism, leading to abnormalities in sex organs, hormonal dysfunction, and metabolic issues (Mnif 2011; Swedenborg 2009).

Reduced nutritional quality of crops

Many factors affect the nutritional quality of the crops, such as soil health, soil composition, the variety of the crops, climate, use of pesticides, fertilizers, and the farming practices employed. Monocropping beans and corn has been shown to decrease the nutritional content of crops in comparison to intercropping (Mukhala 1999). Monocrops require higher pesticide input, which has been shown to affect the nutritional value of the crops produced. Some studies have shown that the use of fertilizers can increase the yield and nutritional value in crops such as cereal, oilseed, tuber plants and vegetables (Hornick 1992). The use of fertilizers in excess can, on the other hand, lead to undesirable effects, such as nitrate accumulation and decrease in the concentration of vitamins and minerals (Wang 2008).

The indirect effect of monocropping in human health

Industrial animal agriculture is more resource-intensive than other forms of food production (Horrigan 2002). In comparison to low-income countries, where most of the crops are consumed directly, high income countries feed 60% of their crops to livestock, and subsidies that facilitate monocropping practices for corn and soy production make it cheaper to plant vast amounts of land with these crops in order to feed livestock (Walker 2005). This, in consequence, reduces the cost of meat, facilitating diets high in meat and saturated fats, but low in fruits, vegetables, and other nutritious foods. These diets increase the risk of cardiovascular disease, such as stroke, heart disease, diabetes and cancer, which are the leading causes of death in the US (Walker 2005).

An often-overlooked aspect of meat consumption that affects human health is bioaccumulation. Contaminated soils and crops with pollutants such as dioxins, furans and polychlorinated bromides are fed to animals, and these pollutants accumulate in the animal's fat reserves. Diets high in animal fat tend to have higher levels of these contaminants, which are toxic, can be carcinogenic, and have been found to contribute to developmental disorders in children (Walker 2005). Bioaccumulation also plays an important role in antibiotic resistance, since antibiotics that are commonly used to treat human conditions are fed to poultry in large quantities to increase their growth, and these will accumulate in animal tissue. The rates of antibiotic-resistant bacteria have increased in recent decades, and these antibiotic resistant bacteria can be passed to humans through animal consumption (McKenna 2017). Regenerative agriculture practices facilitate the production of nutritious and healthy foods because these practices prioritize crop diversification and reduce the amount of toxins in the diet by reducing the usage of synthetic pesticides and fertilizers.

II. Policy Background

The conventional farming practices used today are the result of a long history of policy and economic development within the United States. Propelled by the challenges of the tumultuous 1930's, agriculture has been molded to keep up with the growing demands of the nation. Agricultural policy, which is shaped by the Farm Bill, has also shifted to accommodate industrialization, surpluses, and growing influences of other industries. To fully understand how the system can be changed, it's critical to examine the deep roots that conventional

farming has sown through a political and historical lens.

i. The Farm Bill

The Farm Bill is renegotiated and passed approximately every five years, with the most recent one having passed in 2018 (US Congress 2018). It was originally enacted in the 1930's as part of FDR's New Deal, in response to the Dust Bowl and the Great Depression. It was intended to "keep food prices fair for farmers and consumers, ensure an adequate food supply, and protect and sustain the country's natural resources" (NSAC n.d.). Since then, it has evolved to keep up with the changing and growing needs of the agriculture industry. It currently contains twelve sections, or "titles": commodities, conservation, nutrition, credit, rural development, 'research, extension, and related matters,' forestry, energy, horticulture, crop insurance, and miscellaneous. Both the House and the Senate have committees on agriculture, which write out their proposals for the bill and then must come together to reach agreements and propose one unified version of the bill, which is then further revised and eventually voted on. The bill then undergoes a rigorous appropriations process, which involves the president's proposed budget, the House and Senate budget committees, and the House and Senate appropriations committees. Once the bill is passed by Congress, the US Department of Agriculture (USDA) decides on and executes the rules for the implementation of the bill. The 2018 Farm Bill is estimated to cost $428 billion over its five-year course, with the following estimated breakdown in categories: Nutrition (76%), Crop Insurance (9%), Conservation (7%), Commodities (7%), and Other (1%) (NSAC n.d.).

Conservation programs

The Farm Bill involves several major environmentally geared programs that aim to assist farmers with integrating more sustainable farming practices and helping to conserve land, including the

- Environmental Quality Incentives Program (EQIP)
- Conservation Stewardship Program (CSP)
- Conservation Reserve Program (CRP)
- Sustainable Agriculture Research and Education Program (SARE)

The Environmental Quality Incentives Program is geared towards providing individualized assistance to farmers to modify their practices to include cover-cropping, nutrient and irrigation management, prescribed grazing, fencing, forest improvement, and other regenerative agriculture techniques (Farm Bureau n.d.). As of 2017, 11.6 million acres of US land were in active or completed EQIP contracts (USDA n.d. b), with the largest proportions of land being in Texas, followed by New Mexico. The 2018 Farm Bill increased EQIP's funding by over $1 billion, bringing the total budget authority to $21.3 billion over a 10-year period. This money is intended to be divided between financial support and technical assistance to farmers utilizing the program. Some of the notable changes from this new funding under this Farm Bill are increased reimbursements associated with the implementation of regenerative practices, the introduction of five to ten-year incentive programs for resource and wildlife habitat preservation, and the reduction of the program's focus on livestock-based initiatives from 60% to 50%. EQIP's funding makes up 31% of the USDA's budget for conservation programs (Farm Bureau n.d.).

The Conservation Stewardship Program provides assistance to farmers to maintain pre-existing conservation systems. With 77 million acres of US farmland and forestland tied to CSP contracts, it is the largest conservation program in the US by acreage. To apply for the program, applicants must meet a "stewardship threshold" based on the number of resource concerns faced by their land and agree to meet certain conservational thresholds over a 5-year period. This qualifies them for annual payments based on their performance. There was talk of eliminating CSP with the 2018 Farm Bill, and while this did not happen, its budget authority was cut by around $4 billion, bringing it to $15.2 billion over a 10-year period. The most recent Farm Bill increased incentive payments for cover-crop practices and set aside special funds to help farmers transition to organic production, changed CSP from an acre-based program to a dollar-based program

like EQIP, and enabled new applicants to compete with renewals for priority based on the projected environmental benefits (Farm Bureau n.d.).

While these numbers seem large, spending on conservation programs make up only about 7% of the total farm bill spending, which is low given the breadth of the issues they aim to cover and the increased threats to farming and food sustainability posed by climate change. Analysis done by the Union of Concerned Scientists found that CSP functions could almost quadruple the value of every taxpayer dollar invested into it, which is higher than the return on investment from most other federal conservation initiatives (Stanley 2018). There is high enthusiasm for the program among farmers, yet it is historically underfunded, with 50-75% of applying farmers being turned down. Some of the CSP functions are to pay farmers to retire land, help finance crop rotations, manage intensive rotational grazing, employ cover cropping, and establish wildlife habitats. The CSP also realizes that these practices are financially beneficial when done in combination, and it aims to execute them in that way. For farmers, cost savings from the CSP could be achieved through decreased spending on fertilizer. For example, for 2021 in Illinois the cost of fertilizer is estimated to be around $140 per acre of corn and $56 per acre of soy (Schnitkey 2021). For consumers, savings could come through reduced spending on contaminated water. Another shortcoming of the sustainability initiatives in the 2018 Farm Bill is that they fail to address increased requests from farmers for support. USDA conservation programs have long annual waiting lists and a survey of 2,800 farmers found that three quarters of respondents want to "adopt practices that reduce runoff and soil loss, improve water quality, and increase resilience to floods and droughts" (Delonge 2018).

The 2018 Farm Bill also expanded the Conservation Reserve Program, which removes environmentally sensitive land from use. Some research initiatives, such as the Organic Research Extension Initiative and the Foundation for Food and Agriculture Research and Development Authority, which works to create innovations for increased agricultural sustainability and resilience, received increased funding as well (Stanley 2018). Offshoots of the bill also provide resources for farmers, such as the *Building Sustainable Farms, Ranches, and Communities: A Guide to Federal Programs for Sustainable Agriculture, Forestry, Entrepreneurship, Conservation, Food Systems, and Community Development*, which was published by the Sustainable Agriculture Research and Education Program (Richards 2020). When SARE was founded in 1990, Congress established that it should receive no less than $60 million in annual funding, per recommendation from the National Academy of Sciences. While ecological concerns have only increased since then, appropriations have never reached this level and are currently at around half of this amount. Furthermore, the 2014 Farm Bill made it so that SARE had to be reauthorized with each new bill. The 2014 Agriculture Appropriations Act also consolidated the research and professional development portions of SARE into one program and delegated funding determinations to the USDA rather than Congress. While there are resources available, it is clear that the lack of funding to these programs severely reduces the ability of farmers to access them (Department of Agriculture n.d.). Systemic racism in the USDA's decision-making process when accepting loan or grant applicants has also played a tragically significant role in the ability of farmers of color to employ regenerative techniques (Rosenberg 2019). While our review does not give this topic the attention it deserves, it is always a key aspect of the US agricultural sector.

Subsidies

Agricultural subsidies are another important aspect of the Farm Bill, which are addressed in Title 1: Commodities. The US government currently subsidizes corn, soybeans, wheat, cotton, and rice, which are the nation's most produced crops and are generally grown as monocrops. The 2014 Farm Bill eliminated the controversial direct payments to farmers, converting all subsidies to insurance premium coverage. This is important to farmers because they need insurance to take out crop loans, without which they would be unable to run large, high-yield farms (Smith 2015). As of 2017, Texas, Nebraska, Arkansas, and Illinois received the highest

amounts of subsidies, collectively getting 38.5% of the $7.2 billion given that year (Amadeo 2020). Peanuts, sorghum, and mohair receive smaller subsidies, and meat, fruit, and vegetable producers are only eligible for insurance or disaster relief. According to research published in the *Environmental Working Group,* the Federal Crop Insurance Program, which is part of the Farm Bill commodity title, encourages farmers to plant the same crops using the same methods, year after year (Schechinger 2017). The program aims to provide stability by guaranteeing that farmers' incomes won't fall below a certain percentage that is determined by averaging their actual crop yields over their production history. However, through the Actual Production History Yield Exclusion, which was added in 2014, the government can exclude many low-yield years from this calculation, making insurance payouts artificially inflated (Schechinger 2017). Furthermore, this ignores the reality of failed crops in changing climate conditions, which are particularly hitting the Midwest as temperatures continue to rise and drought becomes more common. Significant portions of subsidized crops are also grown to feed cattle, and for cotton that is shipped overseas to produce clothing. It is also important to note that subsidies include food stamp considerations, which encourages congressional representatives from urban districts to support the bill.

It is important to consider that as of the 2014 Farm Bill, $134 billion was projected for commodity spending over the coming decade. Meanwhile, specialty crop growers (non-commodities) would receive $4 billion, split between various programs and research grants, over the same period. Beyond the difference in subsidization, there are also barriers in terms of commodity support setups for specialty crop farmers. There are those who prefer to avoid getting involved with commodity subsidies because of the regulation that comes along with them (Haspel 2014). To provide adequate insurance, the government must have a way to monitor the yields, which comes with high levels of oversight and encourages monocropping, something that smaller scale specialty farmers are averse to. The 2014 Farm Bill did allow for commodity farmers to devote 15% of their land to specialty crops without losing benefits of the insurance programs. While this is a good step away from monocropping, it will significantly impact the market for smaller scale, non-subsidized farmers.

ii. The New Deal

Before the Great Depression of 1929 and the creation of President Roosevelt's New Deal, there were several actions established by Congress to support US farmers. Due to the stock market crash, "farm foreclosures were becoming so widespread that the whole traditional system of land owning seemed threatened" (Rasmussen 1983). By the early 1930s, further government intervention was crucial for the survival of US commodity prices, farms, and farmers.

Overview of the New Deal

Upon his Presidential election, Roosevelt brought with him the New Deal. Roosevelt took his position during a time of dire need in US history. The New Deal included many federal policies and implementation plans within various sectors of government as a means to lift up and strengthen the United States' economy as well as safeguard its citizens' livelihoods. In 1933, with Henry A. Wallace as Secretary of Agriculture, the agricultural sector saw several policy changes through the creation of the Farm Credit Administration, the Civilian Conservation Corps (CCC), the Emergency Farm Mortgage Act, and the Agricultural Adjustment Act (Venn 1998). The New Deal brought major programs to the agricultural sector between 1933 and 1940 such as "price support and production adjustment, crop insurance, disaster relief, resettling farmers from poor land and aiding tenants to acquire farms, soil conservation, rural electrification, farm credit, and food distribution" (Rasmussen 1983). Referencing the assistance programs in 1934, Secretary Wallace wrote:

"The present program for readjusting productive acreage to market requirement is admittedly a temporary method of dealing with an emergency. It could not be relied upon as a permanent means of keeping farm production in line with market requirements. From a national standpoint it has the

disadvantage that it takes out of production both the efficient and inefficient areas ... A temporary and varying reduction in the productive acreage seriously disturbs the farm economy." (Rasmussen 1983)

The New Deal was successful in maintaining the overall structure of traditional US agriculture, but it also laid the foundation for the role that the federal government continues to play within agricultural support and subsidies. "All of [the New Deal] programs, with one exception, are still in effect. The exception is the program for resettling farmers from poor land and aiding tenants to acquire farms" (Rasmussen 1983).

Assistance programs

Agricultural subsidies have played a big role in incentivizing certain practices, like the farming of single crops on vast amounts of land (monoculture) such as corn, soy, and wheat due to their profitability and versatility to generate fuel and food for both livestock and humans. While this was intended to be a support for farmers and consumers during an economically and agriculturally difficult time in the US, it resulted in the development of a great dependence on these crops for our economy and food supply, as Secretary Wallace was referencing when he wrote about how the assistance programs were not a permanent fix. Such practices also have substantial consequences for the environment and human health. Some of the assistance programs discussed in this section are:

- Agricultural Adjustment Act (AAA)
- Farm Security Administration (FSA)
- Farmers Home Administration (FHA)
- Marketing Loan Program (MLP)
- Federal Surplus Commodities Corporation (FSCC)
- Supplemental Nutrition Assistance Program (SNAP)
- Rural Electrification Administration (REA)

One of the first policies that sought to help farmers with economic losses and controlled what could or could not be planted was the Agricultural Adjustment Act of 1933. The AAA was passed with the goal of strengthening the existing agricultural structure as well as increasing the purchasing power of farmers and their consumption of industrial agricultural products (Rasmussen 1983). The act offered stipends to farmers to reduce acreage in production while guaranteeing minimum prices for the crops grown within the limited acreage. By limiting the production of commodity crops, such as cotton, peanut and soy, and subsidizing farmers for their losses, the policy aimed to lift food prices to those before the Great Depression. This policy was initially struck down by the Supreme Court in 1936 but another version was passed in 1938. Through the inclusion of a federal crop insurance program, this act hoped to continue to offer price support to farmers and in return farmers would reduce their acreage in production (Rasmussen 1983). Many modifications have been made to this act, but it remains the foundation for the agricultural subsidies and federal farm support programs that exist today (Britannica n.d.).

The Resettlement Administration was created as an independent agency in 1935 in response to continuous ridicule of the AAA for its failure to assist the poorest farmers and sharecroppers. This administration held the goal of providing both short-term relief for impoverished farmers and farmworkers as well as long-term assistance in rebuilding the land and lives of those in vulnerable populations within the agricultural sector (Rasmussen 1983). By 1937, it transitioned into an agency within the USDA as the Farm Security Administration "to undertake a tenant purchase program, with the government buying land to be sold under long-term contracts at low interest rates to disadvantaged farm families" (Rasmussen 1983). All resettlement programs within the FSA were liquified in 1943, which left impoverished farmers without federal assistance yet again. In 1946 led to the FSA was succeeded by the Farmers Home Administration, which centered its attention upon increasing farmers' access to production and subsistence loans through a system of insured farm mortgages. By the 1980s, the FHA was still operating within the USDA with a focus on rural development and providing low-cost loans to farmers with credit troubles (Rasmussen 1983).

The Marketing Loan Program was a federal program, initially established in 1930, which subsidized the planting of specific commodity crops by reimbursing farmers if those crops fell below a certain market price. However, if the prices of commodity crops fell, the policy incentivized the increase of the production of such crops anyway, thus driving down prices. The more the price of the crop decreased, the higher the reimbursement would be. Therefore, the policy "has moved from providing price support to providing income support without supporting market prices" (Wescott 2001). Such programs have incentivized farmers to capitalize on the situation, making more money through reimbursement than through actual sales. The meat and dairy industries also benefit from these outcomes because of lower feeding costs for livestock. Altogether, these programs favor overproduction of subsidized crops since farmers can capitalize on drops in market prices.

The New Deal also sought to address the paradox of the plight of city consumers and hungry people while having an increasing food surplus. To manage this crisis, the Federal Surplus Relief Corporation that transitioned into the Federal Surplus Commodities Corporation was created to organize the food purchase and distribution relief program in 1933. By 1935, the FSCC received permanent financing through the allocation of 30% of earnings from commodity crop imports towards encouraging domestic consumption and exporting agricultural commodities (Rasmussen 1983). This method of financing surplus commodity programs has persisted for over 50 years. Frederick Waugh, an agricultural economist, proposed a price program in 1938 with the objective of increasing the consumption of surplus foods in the US. This price program was put into effect in 1939 on an experimental basis, and by 1971, food stamps began "to dominate the food distribution program and became the principal vehicle for attempting to assure every American an adequate diet" (Rasmussen 1983). Food stamps are now known as the Supplemental Nutrition Assistance Program and are operated under the USDA's framework.

Another loan program aimed at bringing electricity to rural areas was presented as an executive order within the New Deal through the Rural Electrification Administration. In 1933, only 10% of US farms had electricity, so the REA advanced funds at low interest rates to rural electric cooperatives (Rasmussen 1983). By 1941, 35% of farms had electricity, and by 1979, the percentage of farmers with electricity rose to 99%. The REA did successfully bring rural areas electricity, but failed to indirectly decrease the flow of people moving from farms to cities, which dramatically increased due to the national droughts of the 1930s.

Soil conservation

President Roosevelt's first step towards stabilizing the US agricultural sector was his executive order to consolidate all federal agencies dealing with agricultural credit into the Farm Credit Administration. A few days later, Congress passed the National Industrial Recovery Act that created the Commodity Credit Corporation (CCC). The CCC was established with the guidance of Hugh Hammond Bennet, a USDA soil scientist, after a series of droughts that triggered the occurrence of dust bowls within the Great Plains (Rasmussen 1983). Major soil erosion led to crop failure and a mass exodus away from farms and towards cities. Bennet "took on the challenge and came to be regarded as the father of soil conservation" (Helms 1991). In Bennet's *Soil Erosion: A National Menace* (1928), he declares "erosion... as the result of artificial disturbance of the vegetative cover and ground equilibrium [occurs] chiefly through the instrumentality of man and his domestic animals" (Bennet 1928). The US government took Bennet's efforts one step further with the financed support of the Public Works Administration and the creation of the Soil Erosion Service. By 1935, the Soil Erosion Service was transferred to the USDA, and shortly after, Congress passed the Soil Conservation Act (Rasmussen 1983). This act declared its agreement with Bennet's stance that soil erosion was in fact a national menace and "transformed the soil conservation work from a temporary status to a permanent agency: Soil Conservation Service" (SCS) (Helms 1991). This

change included a shift toward working hands-on with farmers, including flood surveys and control plans, drainage and irrigation support, and demonstrations of conservation techniques (Living New Deal n.d.). The Agricultural Conservation Program worked side-by-side with the SCS, focusing on "cost-sharing conservation practices in direct cooperation with farmers" through a short-term lens rather than in a long-term perspective (Rasmussen 1983). Although a significant emphasis was placed on soil conservation with the New Deal, soil erosion is still considered a major threat to US farmers, farms, and agriculture and food systems.

iii. Policies regulating pesticide usage in the United States

If we hope to decrease or eliminate pesticide use through regenerative agriculture, it is important to understand how our current system perpetuates the reliance on them. In this section we discuss the history of pesticides and some key policies regulating their usage:

- Environmental Protection Agency (EPA)
- Federal Environmental Pesticide Control Act (FEPCA)
- Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
- Federal Food, Drug, and Cosmetic Act (FFDCA)

Pesticide usage dates to pre-Roman civilizations and up until the 19th century most pesticides were botanically derived. Then, during the late 19th century, the use of arsenicals as insecticides was discovered and increased significantly during the 20th century (Graham 2019). Around the same time, there was a growth in agricultural technology which led to the adoption of large monoculture farms which were more susceptible to pests. Together, the growth of available synthetic pesticides and expansion of pest-susceptible monocrop farms led to a massive increase in synthetic pesticide usage in the 20th century (Graham 2019).

In 1970, there was growing public concern over synthetic pesticide usage, which led to the creation of a new government agency, the Environmental Protection Agency. The Federal Environmental Pesticide Control Act formally shifted enforcement of pesticide regulation from the USDA to the EPA. To this day, the EPA is the main government organization to regulate pesticides in the US and does so based on the Federal Insecticide, Fungicide, and Rodenticide Act and the Federal Food, Drug, and Cosmetic Act (FFDCA) (US EPA n.d.). Some states, including California, have their own EPAs, which develop state-specific regulations that are stricter than the US EPA.

Under FIFRA, registration and re-registration of a pesticide every 15 years is based on the finding that the chemical does not cause "unreasonable adverse effects on man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide." This means that the EPA performs a cost-benefit analysis that includes factors other than human and environmental health. This leads the EPA to overvalue economic and social benefit (Public Employees for Environmental Responsibility 2020), while not requiring the EPA to analyze if the goal of the pesticide could be achieved through other methods. Furthermore, under FIFRA, pesticides are approved based on the safety data of each individual ingredient and does not take into account the synergistic effects that can occur among multiple ingredients or when the pesticide is exposed to different environmental conditions (Public Employees for Environmental Responsibility 2020). Another major issue with FIFRA is that banning pesticides is a very costly process for the EPA because the law allows the pesticide company to challenge the cancellations. This leads to the restriction of the pesticide rather than the complete cancellation. When comparing pesticide approval status between the world's four largest agricultural economies, a major study found that the US EPA allows the use of 85 pesticides that are banned in the E.U., Brazil, and China (Donley 2019). Under FIFRA, the EPA can conditionally register a pesticide under an emergency use exemption, meaning that they can allow the use of the pesticide without any safety data

submitted to the EPA. The EPA's policy does not cover insecticide-coated seeds even though they have been shown to have detrimental environmental impacts (Public Employees for Environmental Responsibility 2020).

Examining the various shortcomings of synthetic pesticide regulation in the United States explains why many harmful pesticides remain in the market. However, there is still the major question of why farmers continue to use synthetic pesticides in their agricultural practices. The answer to this question mainly comes down to the economics of their business. Farmers will use pesticides if the net value of returns is positive (Wilson 2001). If it is more profitable to use pesticides, which improve yields in the short term for a lower cost, than more sustainable methods. However, in the long term, pesticide usage negatively affects yields via soil depletion, pest resistance, contaminated runoff, and other damaging effects (see Science Background section). Once pesticides are in widespread use, it is very expensive to revert to sustainable practices (Wilson 2001). To make the switch to sustainable practices requires time and money. Upfront costs of more diverse equipment, investment in soil health with cover crops, compost applications, and hedgerows will reduce long term input costs but those financial benefits may not be seen for years (Carlisle 2019). There is a higher labor demand with regenerative agriculture compared to industrial agriculture, which replaced human labor with machines (Carlisle 2019). The time it takes to convert the land to regenerative practices varies greatly on the starting quality of the soil and can take anywhere from three to five or more years before the farm is fully transitioned and profitable (Paniagua 2019).

Furthermore, the current practice is that farms decide individually if they want to make the switch to sustainable practices. If one farm changes to biological pest control methods but the neighboring farm is still using synthetic pesticides, it will be very difficult because the pesticides in the nearby ecosystem are killing the predators of the pests that the sustainable farmer is relying on to provide natural pest control (Wilson 2001). However, switching away from this synthetic pesticide trap is possible and has been done in countries such as Indonesia, Sweden, Norway, Denmark, Netherlands, and Guatemala with the help of economic and political commitment (Wilson 2001). Other reasons as to why farmers are not adopting pesticide reduction practices include lack of education about the risks of pesticides as well as the understanding of long-term loss of profitability with pesticide usage. Furthermore, chemical companies strongly push their products through advertising which often biases their use.

III. Stakeholder Analysis

Transitioning away from our current conventional agricultural system to the regenerative agricultural practices outlined thus far will require the careful coordination of various stakeholders. One main challenge is that various players continue to disagree on the extent of advantages regenerative farming can provide. Furthermore, powerful vested interests who have benefited from conventional agriculture remain a major obstacle to the adoption of regenerative practices. The following stakeholder analysis can be used by policy makers as a management tool to help guide coordination with these various players. Based on the interests and power of these stakeholders, they have been grouped by recommended approach into the following categories: manage closely, keep satisfied, keep informed, and monitor.

i. Manage closely

Agribusiness Companies

Powerful stakeholders in agriculture such as oil, fertilizer, and pesticide companies, as well as large industrial farms, have greatly profited from the current conventional farming practices and have a strong desire and lobbying capacity to maintain their foothold in the industry. Fertilizer, pesticides, and oil-powered machinery are heavily used on the large-scale industrial farms of today. All three industries are inherently linked because synthetic pesticides and fertilizers are petrochemical-derived (Kelly 2020). Regenerative agriculture calls for the significant reduction or elimination of these outside resources and would thus drastically reduce the economic viability of these industries.

With the growing public concern over climate change, these industries have positioned themselves as part of the solution to climate change and are marketing their products with "regenerative agriculture" labels (Kelly 2020). Bayer, the manufacturer of glyphosate-based pesticides, has begun advertising their pesticides along with GMO seeds to be used with reduced tillage or no-till practices under the guise of regenerative methods to promote carbon sequestration in the soil (Kelly 2020). This is leading to a new soil carbon market where large corporations can buy carbon offsets from farmers who are sequestering carbon through no-till and other regenerative agricultural practices (Ashtekar 2020). Big Food companies such as Stonyfield, General Mills, Cargill, Danone, and Walmart are all making pledges to cut carbon emissions and are looking at their agricultural supply chains to sequester carbon to help them achieve these goals (Wilcox 2021). However, it remains unknown how long the carbon can be stored in the soil, how much can be sequestered, and whether carbon sequestration can reverse climate change without other large systemic changes (Kelly 2020). If the industry continues down this path, it will be important to verify how companies are measuring and reporting their carbon sequestration (Wilcox 2021). Ultimately, continuing pesticide usage is against the pillars of regenerative agriculture and is known to disrupt soil health even with the incorporation of no-tillage (Kelly 2020).

Over time, there has been a shift in industry awareness and promotion of regenerative agriculture. In September 2019, an international coalition of companies launched the One Planet Business for Biodiversity (One Planet Business for Biodiversity n.d.) at the UN Climate Action Summit. OP2B states that it is determined to protect and restore biodiversity through scaling up regenerative agriculture and eliminating deforestation. The coalition is made up of twenty-one companies and led by the CEO of Danone (One Planet Business for Biodiversity n.d.). In addition, General Mills has started a program where they provide farmers financial assistance to change their farming practices towards more regenerative ones. They pay for monthly one-on-one coaching, finance soil sampling, and help the farmers create custom transition plans (Wozniacka 2019). As more companies start to promote regenerative agriculture it will be important to ensure they are actually changing their practices and not simply "greenwashing": a common industry practice where companies exaggerate how environmentally friendly their products are, capitalizing on the growing consumer demand for environmentally sound practices.

Agricultural Lobbyists

Various lobbying groups who represent the US agriculture industry will play an important role in any agriculture policy reform. Some of the largest of these lobbying groups include the American Farm Bureau Federation, the National Council of Farmer Co-ops, and CropLife America. The American Farm Bureau Federation (AFBF) is an insurance company and lobbying group and includes a network of affiliated state-level Farm Bureau insurance providers. They have historically been known for pushing against climate legislation and have worked closely with the fossil fuel industry to defeat any efforts towards the creation of climate legislation (DeMelle 2021). However, in November 2020, the AFBF announced it had joined an alliance of food, forest, farming, and environmental groups that will work with the new administration to reduce the food system's impact on climate. This new alliance is made up of the Environmental Defense Fund, the Nature Conservancy, the National Council of Farm Cooperatives, the National Farmers Union, and others (Gustin 2020).

The National Council of Farmer Co-ops (NCFC) is a group of regional and national farmer cooperatives with the mission to "advance the business and policy interests of America's cooperatives and other farmer-owned enterprises." In 2018 they had $1,512,600 in lobbying expenditures (NCFC n.d.). In the past, the NCFC, along with the Farm Bureau, argued against "cap and trade" legislation which would limit emissions to slow global warming (Charles 2020). However, in recent years their statements have aligned with the goals of regenerative agriculture. In 2015, they released a statement that they joined Field to Market: The Alliance for Sustainable Agriculture, a

multi-stakeholder initiative working to unite the agricultural supply chain to advance sustainable food, fiber, and fuel production (Field to Market 2015). Further, in 2020, the NCFC along with twenty other farm and ranch groups, formed the Farmers for Sustainable Future, a group committed to environmental and economic stability. This coalition consists of several Big Agriculture organizations including the previously discussed AFBF, the American Sugar Alliance, American Soybean Association, National Cattleman's Beef Association, United Egg Producers, and the US Canola Association, among others (Targeted News Service 2020).

CropLife America is a powerful lobbying organization which in 2020 consisted of ten lobbyists with $1,691,405 in total lobbying expenditures. Five out of the ten CropLife lobbyists previously held government positions, further emphasizing the political power of this group (OpenSecrets n.d.). They are a large player in the discussion surrounding the Farm Bill and hosted a debate on shaping the 2012 Farm Bill (PRWeb 2010).

Federal Agencies

The USDA is the federal executive department in charge of developing and executing federal laws related to farming, rural development, and food, and includes twenty-nine agencies with a total annual budget of around $150 billion (Muller 2020). During the Trump Administration, the USDA was led with climate change-skepticism and hid a multiyear plan the agency had developed to help agriculture adapt and minimize the effects of climate change (Evich 2019). The USDA has historically been swayed by the large lobbying groups on aspects of the Farm Bill and most of their programs operate within conventional farming structures and practices. However, there does seem to be a push towards advancing regenerative agriculture. The Climate 21 Project collaborated with USDA officials and created a memo which includes steps for the USDA to address agriculture's contributions to climate change and how to overcome risks from climate change (Muller 2020).

The EPA regulates pesticide and agrochemical usage and thus would not be opposed to their minimized usage. The goals of the EPA of protecting the environment and maintaining clean water align with the practices of regenerative agriculture. The EPA recently released data documenting the agricultural industry's rising emissions, which now account for about 10% of the total US emissions (Lillison 2021). These agriculture related emissions include methane, nitrous oxide, and carbon dioxide, which have all increased since 1990 (Lillison 2021). Much of this is due to the conventional farming system which relies on fuel for farm machinery and synthetic fertilizer production (Lillison 2021). The current Biden administration has reentered the Paris climate agreement and will set new emission reduction goals for the country. This EPA finding on the growing contribution of emissions from agriculture, in conjunction with a more climate-focused administration, will likely contribute to changes in agriculture policy to cut emissions within the industry.

ii. Keep satisfied

The oil industry, fertilizer industry, and members of Congress are examples of stakeholders who also hold a lot of power over agricultural policies and thus need to be considered when making any policy recommendations.

Oil and Fertilizer Industry

As mentioned earlier, the oil industry is heavily involved and relied upon by current conventional agricultural farming practices. From 2000-2016, more than $2 billion was spent on lobbying both for and against climate change legislation in the US with the fossil fuel industry spending $554 million on climate-related lobbying spending. Meanwhile, environmental organizations spent $48 million, representing only 2.3% of total climate lobbying (Brulle 2018). Since current farming practices rely so heavily on fossil fuels, farmers have voiced concerns over a carbon tax and the fossil fuel industry has lobbied against carbon taxes in the name of supporting farmers.

Similarly, the fertilizer industry's profits are tied to

conventional agriculture. As discussed previously, this heavy use of synthetic fertilizers is detrimental to the goals of regenerative agriculture. Nitrogen fertilizers require a large amount of energy to produce and thus account for 1-2% of total global energy consumption and supplies of nitrogen fertilizer are expected to grow nearly 4% per year over the next decade (Down To Earth 2015). Similarly to the chemical pesticide industry, these fertilizer companies are trying to position themselves as part of the solution to agriculture and climate change.

Members of Congress

Members of Congress have varying levels of interest in agricultural policies based on whether they represent agricultural states or not. Furthermore, as mentioned previously, agriculture and climate change policies are subject to intense lobbying efforts, which may influence members of Congress. There seems to be a push for regenerative agriculture policies with some members of Congress. Some examples include the Agriculture Resilience Act sponsored by Representative Pingree of Maine as well as the Climate Stewardship Act of 2019 sponsored by Senator Cory Booker of New Jersey. The Climate Stewardship Act of 2019 proposed incentives for agricultural producers to carry out climate stewardship practices and to provide for increased reforestation across the US The Sustainable Agriculture Research Act sponsored by Representative Neguse of Colorado in 2021 aimed to amend the National Agricultural Research, Extension, and Teaching Policy Act of 1977 to enhance the role of agriculture in innovative sustainability solutions. Identifying allies in Congress will be helpful to advance regenerative agriculture policies. The House Agriculture Committee as well as the US Senate Committee on Agriculture, Nutrition, & Forestry members are key stakeholders as they oversee and direct legislation pertaining to agriculture.

iii. Keep informed

Key Allies: Environmental Organizations, Farm Communities, Medical Professionals

Several key stakeholders exist that do not hold as much power as those mentioned above but act as key allies in the conversation around regenerative agriculture. These groups include environmental organizations, local farm communities, doctors, public health advocates, and extension programs. Small and midsize farmers are slowly adopting regenerative farming and can serve as educational resources and provide testimonials for other farmers in transitioning from conventional to regenerative farming practices. Organizations advocating for environmental and climate policies would also be supportive of regenerative agriculture since regenerative agriculture sequesters carbon from the atmosphere, helping to mitigate carbon emissions. Furthermore, regenerative agriculture practices work to promote local ecosystem health and diversity by improving soil health and eliminating the reliance on synthetic pesticides and fertilizers. Farm-adjacent communities have an interest in the agricultural practices happening near their homes, especially when pesticides and fertilizers can seep into local drinking water. Nutritionists, doctors, and other public health advocates would support regenerative agriculture practices due to the detrimental health effects of conventional farming. The current agricultural system and subsidies promote unhealthy diets that cost the healthcare system more than $50 billion annually. Lowering the prices of fruits, vegetables and other nutritious food can help mitigate healthcare costs related to diabetes and other diseases. A decrease in soil quality can lead to a decrease in nutrients from the food we eat. Controlling the pesticides present in our food would greatly interest public health advocates because of the negative health consequences of these chemicals in our food system. Extension programs already support small farms that engage in regenerative and sustainable agriculture practices and thus would support additional policies to expand these practices.

iv. Monitor Consumers and Farm Laborers

Additional stakeholders hold little influence and might not initially be interested in regenerative agriculture policies but should still be monitored while enacting policy recommendations. These stakeholders include, but are not limited to, consumers and farm laborers. Consumers might care about farming practices because they do not want

the availability or prices of foods to change. There is also a growth of veganism and environmentally-driven food trends which can influence company advertising and might have a sway over the adoption of regenerative farming practices. Farm laborers are directly impacted by farming practices and would be the people trained in the new methods involved with a switch from conventional to regenerative practices. These farm laborers are also the individuals who experience the highest concentrations of pesticide exposure and thus would greatly benefit from the reduction or elimination of these chemicals from farming. Some of these individuals may be opposed to changing a system they have grown accustomed to, and therefore, understanding their values and bringing them into the conversation will be critical when enacting change.

IV. Policy Recommendations for Enabling Regenerative Farming Techniques

The United States' current agricultural and food system has been created through centuries of changes within culture, climate, access, technology, policy, as well as scientific understanding. This report has examined the fundamentals in the scientific understanding of agriculture and its relationship to natural environments and human health, the past century's evolution of agricultural policy, and the key stakeholders who influence the agricultural system.

With a thorough comprehension of the interests, developments, and vulnerabilities of the United States' current agricultural structure, our team formulated four policy recommendations to reform federal systems. These recommendations work towards creating a supportive platform for farmers to adopt regenerative agricultural practices and move climate-smart agriculture up as a solution for combating climate change. The four main policy recommendations are:

- Enhance the Conservation Reserve Program
- Expand the Sustainable Agriculture Research and Education program
- Increase subsidies for biodiverse and regenerative farming
- Strengthen antitrust enforcement in the agricultural industry

i. Enhance the Conservation Reserve Program

The Conservation Reserve Program (CRP) is a land conservation program run by the Farm Service Agency (FSA) of the USDA. With contracts between ten-to-fifteen years, farmers receive rental payments each year for their environmentally sensitive land to be removed from agricultural production. The fifteen-year agreements are typically intended for tree plantings. CRP goals are to re-establish valuable land cover to help improve water quality, prevent soil erosion, and reduce loss of wildlife habitat" (USDA n.d. a). The benefits achievable with regenerative agricultural techniques coincide with CPR goals. With continuous long-term implementation of less tillage, decreased use of harmful agrichemicals, and increased crop biodiversity, farmlands regenerate soil organic matter which reduces topsoil erosion, preserves groundwater, improves local watershed's water quality, and increases wildlife populations, as well as maximizes crop nutrient-accessibility and production.

We urge the FSA to expand the scope of CRP to include forming contracts with farmers who need support in transitioning previously conventional farmland into regenerative farmland. As the Biden-Harris Administration is trying to leverage the USDA's conservation programs for climate mitigation, this strategy for CRP expansion will incorporate farmers as lead actors in the US's battle against climate change (Farm Service Agency 2021). As previously discussed, the transition period from the use of conventional to regenerative farming practices takes several years before the SOM increases enough to positively impact crop yields. CRP has the capacity to extend its applicant pool to those farmers interested in transitioning to climate-smart farming, but who need financial support during the 10-15 year period of decreased crop production.

Additionally, we urge the USDA's Natural Resources Conservation Service (NRCS), which was recently granted $140 million towards increasing the

technical assistance capacity and impact measurement of CRP, to allocate a portion of its funds towards providing technical support to farmers transitioning from conventional to regenerative agricultural practices (Farm Service Agency 2021). By contributing funds to this strategy of addressing climate change, farmers will become empowered leaders in our nation's efforts and contribute to the implementation of regenerative agricultural practices throughout the country.

The Department for Environment, Food and Rural Affairs of England released *The Path to Sustainable Farming: An Agricultural Transition Plan 2021 to 2024* in November of 2020 to announce their strategy to "renew" the agricultural sector. Involving farms as significant contributors to national environmental goals, addresses climate change and transitions farms away from subsidy reliance to be profitable and economically sustainable businesses. This plan funds and involves 5,500 of their farmers in co-designing the development of the Environmental Land Management and Sustainable Farming Incentive platforms, which will move towards a full roll-out by 2024 (UK Department for Environment Food and Rural Affairs 2020). The USDA can look to the processes, actions, and measurement tools that England utilizes in their Path to Sustainable Farming as a case-study to guide its own strategy towards supporting farmer's transition to regenerative agricultural practices.

ii. Expand the Sustainable Agriculture Research and Education Program

Funding for sustainable agriculture has been relatively small, specifically for projects regarding agroecological research and development. The overall funding for sustainable agriculture corresponds to under 2% of the USDA total budget (DeLonge 2016). The Sustainable Agriculture Research (SARE) program is the only USDA public program focusing exclusively on sustainable agriculture, and the only program that provides competitive grants for farmers and agricultural professionals. It was founded twenty-five years ago and provides funding in a regional manner. It has successfully helped to implement and establish organic crops in the Southeast and several other states. Similarly, the SARE program can encourage the adoption of regenerative farming practices by farmers in all regions. However, in the past few years, SARE funding has stalled significantly in comparison to other federal programs such as the Agriculture and Food Research Initiative (AFRI), a program that provides competitive funding to scientific researchers to solve challenges that farmers face in agriculture. AFRI-funded studies are published primarily in scientific journals that are often not accessible to farmers. The decision by the USDA's Office of Budget and Programs Analysis to heavily fund a similar program to SARE indicates a preference in formal scientific research rather than research led and performed by farmers. The importance of generating research studied and tested by farmers is shown when other farmers' practices change and benefit from the applicable, accessible, and relevant SARE studies.

Many international institutions related to agriculture such as the World Bank Group and CGIAR recognize the limitation of benefits that result from scientific agricultural research (Water-Bayer 2005; Wettasinha 2014). As they urge the formal research sector to make their studies more useful to small and midsize farmers, these institutions are funding farmer-led research initiatives that engage small to midsize farmers to conduct research that is more relevant and accessible to them. Farmer-led research initiatives that support experimentation with "unique combinations of indigenous knowledge and new ideas from a variety of sources," which have led to innovations of best-practices that can be implemented on other farms with similar ecological contexts (Water-Bayer 2005). US land-grant universities, such as University of Kentucky, are discovering the value of farmer-led research as the backbone of agricultural advances (Pratt 2020). The USDA and the Office of Budget and Programs Analysis should reevaluate the benefits that arise from farmer-led research funded by SARE versus scientific research funded by AFRI.

Since SARE's foundation, funding has grown from $3.9 million in 1988 to $22.7 million in 2020. Although SARE's full authorized funding level is $60 million, funding for the program has remained

around $22 million for over a decade, while the AFRI program's budget has increased significantly. The current funding allocated for SARE is failing to meet the needs of farmers. On average, only 6% of the total farmer-led research proposals submitted to SARE are successfully funded (NSAC 2015). This means that thousands of proposals for sustainable agricultural innovation are left unresearched and unfunded. The 2021 spending bill provided $40 million for SARE, "the highest funding level the program has had in its history, but demand still far exceeds available resources'' (NSAC 2021b).

We urge the USDA's Office of Budget and Programs Analysis to increase SARE's funding to its full authorized level of $60 million. An increased investment in the SARE program will boost research in soil health and climate resilience, which will improve crop production as well as provide assistance to guide farmers towards adoption of climate-smart agriculture.

iii. Increase subsidies for biodiverse & regenerative farming

The United States has over 300 million acres of farmland planted with crops - half are cultivating corn and soy, 50 million acres of wheat, and only around 14 million acres cultivating specialty crops such as fruits, nuts, and vegetables (Haspel 2014). While the initiation of the Federal Crop Insurance Act began in 1938 specifically to minimize the overall impact of the Great Depression and the Dust Bowl on farmers, most of today's 300 million acres are eligible for crop insurance subsidies (Rosa 2019). Current agricultural subsidies still target corn and soy cultivation, and in turn incentivize conventional farming practices such as monocropping and intensive pesticide use. Only about half of all specialty crops are authorized by the USDA's Risk Management Agency (RMA) to be included in the federal crop insurance coverage (Rosa 2019). In contrast to the practice of insuring specific crops, the RMA developed the Whole Farm Revenue Protection (WFRP) insurance policy, which insures revenue for an entire farm. This system of farm insurance provides farmers with more freedom to increase the crop diversity upon their land without diminishing the financial security of being insured.

We strongly encourage the USDA and RMA to incentivize participation in WFRP by providing greater support to insurance companies working with WFRP policies and by increasing farmer engagement. Insurance companies need incentivization and WFRP technical training to cover WFRP policies because these policies are more laborious and time consuming to generate than traditional insurance models (Renton 2020). Because this whole-farm insurance model is still in its early years of implementation, further research must be done to understand the difficulties farmers face when applying for WFRP. Expanding participation in the WFRP is a step in the right direction towards encouraging regenerative farming practices through financial security with transitioning to, or continuing management of, diversified farms that promote climate-smart practices.

Whole Farm Revenue Protection is a United States insurance model that was applied in 2015. Monitoring and evaluation efforts as well as farmer stakeholder meetings by non-governmental organizations around the WFRP model in the US have found that further improvement of the model is necessary for increased participation. Such possibilities include decreasing or eliminating paperwork requirements for production expenses as well as providing further educational efforts to crop insurance agents to improve their understanding of the program (NSAC 2019; Olen 2017). Since WFRP's initial implementation, other countries, such as Serbia, have studied the application of this model into their governance systems. Through research conducted by Serbian Universities, the WFRP can have a positive impact on the growth of insured farms and can strengthen trust between farmers and insurance companies for increased economic stability in crop production (Kokot 2020). Further participation of US farmers who cultivate specialty crops can similarly improve the economic stability for farmers.

iv. Strengthen antitrust enforcement in the agricultural industry

In 2018, the USDA published an article that lays out statistical data from three decades of continuous consolidation within the US agricultural industry (MacDonald 2018). As food systems centralize decisions such as what is produced, how, where, and by whom, farmers' ability to treat their farms as unique agroecosystems is diminished by reduced producer availability and market access. In response to the USDA's findings, the Family Farm Action Alliance (FFAA) published a report in 2020 to document the current condition of consolidation within the agri-food system as well as to frame the social and ecological consequences of this system. FFAA's "The Food System: Concentration and Its Impact" found: "Just four corporations are responsible for 65% of sales in the global agrochemicals market, 50% of the seed market, and 45% of farm equipment sales. In the United States, just four companies represent 73% of beef processing, 67% of pork processing, 54% of chicken processing, and 45% of the retail grocery market."

The USDA centers the cause of consolidation around technological advances: "the equipment used in field tasks—for ground preparation, planting, spraying, and harvesting—has gotten steadily larger and faster, allowing a single farmer or farm family to manage more acres" (MacDonald 2018). The National Sustainable Agriculture Coalition (NSAC), Food & Power, and FFAA indicate that the USDA is ignoring the true cause of such rapid consolidation: the "role policy has played in fostering increasing concentration of ownership at every level of our food production, processing and distribution system" (Carty 2018). The FFAA states that what is necessary for bringing decision-making power back to farmers is the democratization of the agri-food system across local, state, regional and national scales (Hendrickson 2020).

Multiple attempts have been made by policymakers on both sides of the aisle to address practices that eliminate the competitive nature of an industry, but no meaningful reforms have been passed through Congress (NSAC 2021a). The Farm Bill does not acknowledge the corporate consolidation of the food system, instead perpetuating the divide between the largest actors, who control the financial resources and land within the industry, and the smallholder farmers who operate in diverse and niche markets. The dominant actors in each agriculture sector are free to "inflate the prices that farmers must pay for inputs, drive down commodity prices, and restrict the ability of farmers to compete in the marketplace" (Carty 2018). Enhancing antitrust enforcement throughout all levels of the food system is key for encouraging competition and minimizing the consolidation of power within the agricultural industry. One element outlined in President Biden's plan for rural US development is to: "Strengthen antitrust enforcement. From the inputs they depend on - such as seeds - to the markets where they sell their products, American farmers and ranchers are being hurt by increasing market concentration. Biden will make sure farmers and producers have access to fair markets where they can compete and get fair prices for their products - and require large corporations to play by the rules instead of writing them - by strengthening enforcement of the Sherman and Clayton Antitrust Acts and the Packers and Stockyards Act." (Joe Biden For President n.d.).

We urge President Biden to follow through in his commitment to enhancing antitrust enforcement. By releasing the grasp these four corporations hold over the majority of global agricultural sales, farmers who do not follow conventional farming practices will have a competitive sway over the agricultural industry. This issue does not simply hurt US farmers and consumers but has spread throughout the global agricultural industry. President Biden has an opportunity as a leader of an economically influential nation to make the first legal and legislative steps to push against the current status quo set by corporations themselves. We ask the Biden administration to commit to creating a level playing field in the US for regenerative agricultural techniques and perspectives. Empowering US regenerative farmers will enable their voices to be heard at the global table where, currently, only corporations hold power.

V. Conclusion

Through this study, we comprehensively outlined the chemistry of soil to highlight the environmental benefits of regenerative practices such as reduced pesticide use, more judicious fertilizer application, and no-till practices. This is a key component in gaining government support for the implementation of scientifically-backed agricultural practices that benefit human and ecological health. Conventional farming has become deeply rooted within our economic and production systems in large part due to the influence of the New Deal and the needs of the early industrialization period. While there are governmental programs, organizations, and researchers working to transform the US food system, lack of funding, discrimination in USDA programs, and corporate influence over legislation all create barriers that limit the potential of these effort's ability to decrease the agricultural environmental footprint. Our current agricultural system is complex and interconnected with other industries, and thus requires the identification and management of stakeholder goals to successfully transition to a more regenerative agriculture system. We call on President Biden, Vice-President Harris, and their administration to make efforts to support and encourage the adoption of regenerative farming techniques by enhancing the Conservation Reserve Program, increasing subsidies for biodiverse and regenerative farming, expanding the Sustainable Agriculture Research and Education Program, and strengthening antitrust enforcement in the agricultural industry. These policy recommendations, if followed, can help reduce carbon emissions and slow down climate change, empower farmers through incentives for innovation, and reduce food insecurity. Moreover, it can help to heal the land that has suffered from years of industrial agriculture and detrimental practices. Changing the system is possible, although difficult, and we hope that this guide can help play a role in setting the precedent for a different reality - one where we do not take our land and our planet for granted.

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