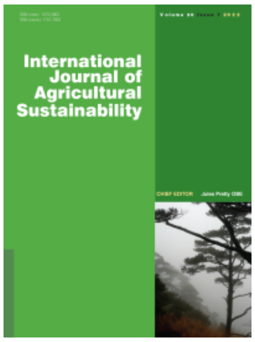

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Drivers and barriers to adoption of regenerative agriculture: cases studies on lessons learned from organic

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ABSTRACT

Regenerative agriculture has emerged as a potentially outcome-based paradigm centring on soil health, biodiversity and other environmental and social parameters. Early days of organic agriculture also focused on philosophy first and evolved into a process-based regulatory paradigm whose adoption remains small relative to conventional production. Five case studies of professional growers, representing a total of 100,000 acres of production, were collected to identify reasons for choosing to grow or stop growing organic, challenges faced and attitudes around regenerative agriculture. Growers identified issues of complex and unpredictable regulation, labour, inability to predict market trends and secure needed premiums, cost and effectiveness of natural fertilizers and lack of effectiveness in pest control. These growers adopted similar practices (e.g., integrated pest management) for environmental benefits across conventional and organic acres, and viewed consumer demand and potential profitability rather than environmental benefits as the main drivers for practising organic. Growers expressed interest in outcome-based regenerative agriculture. To be viable, a programme requires criteria on measurement and certification, regionally tailored flexibility and clear financial incentives. Growers doubt such a programme would replace organic but see opportunities for new marketing programmes, particularly in carbon sequestration and water management. Challenges identified by growers warrant further study.

Abbreviations: EPA: Environmental Protection Agency; FIFRA: Federal Insecticide, Fungicide And Rodenticide Act; IPM: Integrated Pest Management; MRL: Maximum Residue Limit; NOP: National Organic Program; NOSB: National Organic Standards Board; OAP: Organic Approved Pesticide; OFPA: Organic Foods Production Act; OMRI: Organic Materials Review Institute; PAMS: prevention avoidance monitoring suppression; SOC: soil organic carbon; USDA AMS: US Department of Agriculture Agricultural Marketing Service; WASDA: Washington State Department of Agriculture

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Introduction

Production of safe, nutritious, affordable, and sufficient food is one of the greatest challenges facing humanity. Food production is a resource intensive process, requiring land, water, quality seed, fertilizer, and pest control; while the scale and methods have evolved, the overall result has been increased global agricultural productivity over time (USDA ERS, 2020 Steensland, 2022; USDA ERS, 2022). Concerns over environmental degradation

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from agricultural practices, as evidenced by the 1930s dust bowl in the U.S., spurred interest in new techniques such as reduced tillage that would over the following decades become part of a 'conservation agriculture' approach (Derpsch, 2003; CIMMYT, 2020; USDA NRCS, 2023). Over the same time period, organic agriculture also emerged as a potential alternative to 'industrial agriculture' (Mann, 2018). The organic market has enjoyed decades of growth, reaching more than $55 billion annually in U.S. sales in 2020 (Statistics, 2022). Demand for organic products is highest in North America and Europe (Meemken & Qaim, 2018). In the U.S., from 2008 to 2019, the number of certified organic farms increased by 5% and land area under organic production methods increased by 6% (Mpanga et al., 2021). Despite this growth, certified organic agriculture is still a relatively small portion of total land in production, estimated to be about 1% of total agricultural land worldwide in 2015 (Meemken & Qaim, 2018). There are also major differences in the adoption by crop species. Certified organic production plays a larger role for permanent crops, such as berries, coffee, and olives, than for annual crops such as cereals and vegetables (Meemken & Qaim, 2018).

Mpanga et al. (2021) examined agricultural production surveys from the USDA from 2008 to 2019 to investigate state and national trends in U.S. certified organic production. Over that time, the percentage of certified organic farms employing on-farm organic practices declined except for a modest increase for rotational grazing. Declines were seen in several practices associated with pest and weed management, including organic compost/mulch, conservation tillage, location selection to avoid pests, variety selection to resist pests, and use of beneficial habitats and organisms. The two largest challenges reported by certified organic crop producers and ranchers in the U.S. are related to production and regulation. The authors postulated that production issues could be related to soil fertility, weeds, diseases, and pest control. Other challenges included price, market access, and management issues. The authors concluded that to sustain the growth trends of organic production in the U.S., these challenges need to be addressed.

In the context of the United Nations Sustainable Development goals and renewed focus on developing agricultural systems that meet food security needs while treading lightly on the environment, additional sustainable agriculture concepts beyond organic have emerged in recent years such as climate-smart, circular, and regenerative agriculture (FAO, 2019; UN, 2021; Strauss & Chhabria, 2022). The latter has garnered attention in both publications and as part of sustainable sourcing programs (Sustainable Brands, 2020; Unilever, 2022). The term regenerative agriculture is currently ambiguous and lacks a scientific or regulatory definition (Newton et al., 2020; Tittonell et al., 2022). Within the organic production community there has been interest in developing a set of practices that go beyond organic as demonstrated in the Framework for Regenerative Organic Certification (Regenerative Organic, 2019). The goal of this framework is described as promoting holistic agriculture practices that 'Increases soil organic matter over time and sequesters carbon below and above ground, which could be a tool to mitigate climate change; improve animal welfare; and provide economic stability and fairness for farmers, ranchers, and workers.' Others are less focused on using organic certification as a baseline for regenerative agriculture and have set out to define the practices and outcomes of interest. Schreefel et al. (2020) recently conducted a systematic review of literature on regenerative agriculture and of the 28 papers identified, there were 214 objectives and 77 activities described. The largest convergence was on environmental objectives and fell into four main themes: enhance and improve soil health, optimize resource management, alleviate climate change, and improve water quality and availability. There was less convergence on the objectives of human health and economic prosperity, which also often lacked clear definition of activities and had many diverse issues embedded that at present would be difficult to measure. Similarly, Tittonell et al. (2022) describes three broad types of regenerative agriculture that differ in their degree to which they internalize social dimensions. Newton and colleagues (2020) found that definitions of regenerative agriculture contained both processes and outcomes. Among the most cited processes included use of low or no external inputs, integrated livestock, and reduced tillage practices. Among the most cited outcomes included improving soil health, biodiversity, and carbon sequestration. Giller et al. (2021) posited that from an agronomic standpoint, the two challenges most linked to regenerative agriculture are restoration of soil health (including the capture of carbon to mitigate climate change) and reversal of biodiversity loss.

There is currently discussion and debate about the definition of sustainable agriculture (Thompson, 2007; Knickel et al., 2017) and whether regenerative agriculture or another similar paradigm can align incentives to drive the needed changes (FORA, 2021; Giller et al., 2021; Martins et al., 2021; USDA, 2022a). The current status of regenerative agriculture has been likened to the early days of organic agriculture, which was focused on core philosophy and principles (Schreefel et al., 2020). This paper reviews the historical and regulatory foundations of organic agriculture as it may be instructive for understanding how new paradigms are introduced into agriculture. Further, insights from growers were captured to identify areas of current alignment and barriers to advancement of regenerative agriculture. Building on Mpanga et al. (2021), results of the current survey along with discussion are classified into the areas of regulation and its achievement of environmental outcomes, production and farm management, and market access and profitability.

Grower survey

A multiple case study approach was utilized to further explore the results of Mpanga et al. (2021) and assess the applicability of lessons learned from organic to the emerging concept of regenerative agriculture. Growers (n = 5) were recruited by CropLife America, and were selected for the following reasons: The growers in this survey manage very large farms (significantly over the 445 acre average farm size reported in the US by USDA (USDA, 2022b)), the farms they manage are considered family farms, which is defined by USDA as 'the principal operators and their relatives (by blood or marriage) own more than half of the business's assets' (MacDonald & Hoppe, 2017), they represent their peers at advisory board positions and are regarded by their peers as influencers, i.e. innovative farmers who others look towards when making decisions. It is noteworthy that USDA has described family farms as playing a dominant role in U.S. agriculture, accounting for 99% of U.S. farms and 89% of production in 2015 (MacDonald & Hoppe, 2017).

The growers were interviewed about their experiences with organic agriculture to identify reasons for choosing to grow certified organic and specific challenges in organic agriculture related to the categories of regulation, production, management issues, price, and market access. Growers were queried on use of environmental stewardship practices. Finally, the case studies were also designed to gain insights into knowledge and attitudes around regenerative agriculture.

The survey utilized a semi-structured approach and included a mixture of closed and open-ended questions. The full survey can be found in Appendix 1 (note, the questions there were used to guide the interview and were not completed as a written survey by the participants). Responses were transcribed by the interviewer. Growers interviewed represented a diversity of locations and crops across the U.S. (Table 1). All growers were operating farms that are significantly above the average size of 445 acres as reported by USDA (USDA, 2022b) and represent in total approximately 100,000 acres. Two operations were growing 7-20% of their acres as certified organic. One of the growers had not entered organic production and two growers had recently exited certified organic due to barriers they encountered. Growers not currently growing organic discussed the barriers to entry and reasons they exited organic agriculture. Insights were also gained through open-ended discussion on regenerative agriculture and the role of process vs. outcome-based certification programs. While a small sample size, this survey provides

Table 1. Grower location and production characteristics.

Grower	*Production Location (State)*	*Crops*	*Production under organic (% of farm acres)*
1	WA	Apples, cherries, wine grapes	20% certified, 5% in transition
2	IA, NE, ID	Corn, soybeans, wheat, chickpeas	Currently none, took 400 acres through transition period previously
3	CA	Tomatoes, cotton, carrots, garlic, onion, melons, pistachios, almonds, herbs, kale, wheat, alfalfa	7%
4	LA	Corn, soybeans, cotton	none
5	IN	Corn, soybeans	Currently none, tried 20 acres previously

insight into the views of large family farm operations and is representative of the factors that need to be considered for acreage under regenerative agriculture practices to grow.

A literature search was conducted using Google Scholar to identify relevant papers analyzing the definition of regenerative agriculture since 2020.

Regulation as a means to achieve environmental outcomes

To put regulatory challenges in context, it is helpful to briefly review the history of the organic standard and consider lessons that could be applied to the emerging regenerative agriculture paradigm. One of the most fundamental shifts in food production occurred as the result of the discovery and scaling of a method to produce synthetic nitrogen fertilizer, termed the Haber–Bosch process. Nitrogen is a limiting nutrient for many plants, and the ability to add it to the field was responsible for rapid increases in food production after 1913, and many would argue significantly contributed to increased food security (Erisman et al., 2008; Fedoroff, 2015; Mann, 2018). While science had unlocked the ability to increase productivity, use of synthetic fertilizer was not without drawbacks including pollution from nitrogen run off and other practices such as tillage that did not demonstrate an appreciation for, or thorough understanding of, soil dynamics and soil health (Mann, 2018; Kopittke et al., 2019). Use of synthetic inputs such as chemical fertilizers or pesticides that protect plants from insects, weeds, and disease grew over the following decades. The 1940s saw the rise of what was coined 'organic' agriculture by Lord Northbourne to connote 'life giving' food as a juxtaposition to food produced using chemicals (Mann, 2018).

The 1970s saw an acceleration in interest for organic agriculture, influenced by the focus on many environmental issues of that time. Initially, there were no centrally governed standards or regulations to define organic agriculture (SAN, 2007). This was particularly evident when comparing state by state certification programs, which could vary greatly. Creating a level playing field for interstate marketing drove a movement to develop a national organic standard. Congress passed the Organic Foods Production Act (OFPA) in 1990 to develop a national standard for organic food and fiber production. USDA was charged with the development of regulations that would apply to producers and would make certification standardized; those regulations were implemented in 2002. OFPA also established an advisory National Organic Standards Board (NOSB) to make recommendations regarding the substances that could be used in organic practices (SAN, 2007).

USDA organic regulations describe organic agriculture as 'the application of a set of cultural, biological, and mechanical practices that support the cycling of on-farm resources, promote ecological balance, and conserve biodiversity. These include maintaining or enhancing soil and water quality; conserving wetlands, woodlands, and wildlife; and avoiding use of synthetic fertilizers, sewage sludge, irradiation, and genetic engineering' (USDA AMS, 2015a). The principles of organic agriculture and resulting standards represent a combination of practices meant to enhance environmental quality such as crop rotation and cover crop use to maintain soil health and a preference for 'natural' inputs such as manure for fertilizer and plant- or microbe-produced pesticides. As part of the implementation of OFPA, the National Organic Program (NOP) was created to develop the rules and regulations for the production, handling, labeling, and enforcement of all USDA organic products. The NOP can revise and update the rules and regulations as needed, and this process involves input from the NOSB and the public. The NOP also maintains a handbook that includes guidance, instructions, policy memos, and other documents that communicate the organic standards (USDA AMS, 2022).

According to the survey by Mpanga et al. (2021), regulatory challenges were the most frequently reported issue for organic farmers. Growers in the current survey were asked to expound on how regulation creates challenges (summary of responses found in Table 2). Participants identified a close link between regulatory and management challenges as it requires expertise either within the operation or through third-party consultants to manage documentation of certification. This adds cost and complexity to the operation. *One grower stated, '… certification cost me $10/acre. There's a cottage industry of people who have to lead you through it.'* In addition, growers had experienced unpredictability and lack of consistency within the rule setting and certification agencies that hampered their ability to use crop protection products. One grower expressed concern that using tillage as a weed control method instead of chemical herbicides could hamper the ability to comply with other program standards for soil erosion or carbon emissions.

Table 2. Challenges in organic production.

Category	*Grower Responses*
Regulatory	Unpredictability of NOP, inconsistent application of philosophy on excluded products Lack of consistency amongst certification agencies on included products (based on brand name rather than active ingredient) State agencies lack resources and efficiency Cost Concerns that tillage needed would not comply with other program standards for soil erosion control or future regulation related to carbon emission
Production	Yield: size of fruit, tonnage is less Cost Fertilizer is insufficient (cost, supply, and efficiency) Significant labor required to reduce blooms in fruiting trees that experience biannual bloom Isolation distances required from conventional production
Pest management	Lack of effective tools; many diseases and insects are not adequately controlled (e.g. fire blight, codling moth, corn borer and corn ear worm) Lack of post-emergence options for weeds; 'just have to accept weedy fields' Some organic pesticides are non-selective and kill beneficial organisms Growers choose acres with lower pest pressure which limits total amount of organic production and leads to non-ideal matches of variety to other environmental conditions.
Management	Amount of labor; labor shortages Takes a lot more equipment (tractors, mowers) and time Requires paying for specialists to manage the complex and costly certification process Expansion of acres is more difficult Requires more time to monitor fields
Market Access	Must respond to big box store demands Higher risk: some growers use contracts to avoid this (e.g. produce) some cannot (e.g. corn, cotton) Need to make predictions out into the future about amount of demand (especially for permanent crops) Requires more time and sophistication in marketing product to find the best buyer
Price	Commodity prices vary and organic variety prices often follow, which means margin can go down. In some cases, it is not profitable to grow organic. In commodity row crops it is hard to guarantee a premium and there is a greater risk of rejection at the point of sale.
Other	Insufficient H2A guest worker visa infrastructure – an issue for conventional but exacerbated by larger need in organic for labor Global food security

Amongst this group of large-acre professional growers, environmental benefits were not seen as a driver for selecting organic production. Growers were also asked about environmental stewardship practices on the organic and conventional parts of their farm operations (summarized in Table 3). Interestingly, the authors note that use of certain practices such as fertilizer management, cover crops, crop rotation and water use management was fairly consistent between the organic and conventional acres. This may be due to the broad introduction of conservation agriculture practices several decades ago (Kassam et al., 2009).

While the NOP is a well-established certification program, there are other environmental and agronomics researchers developing the body of evidence on best practices for enhancing environmental stewardship and outcomes within agriculture. For example, soil organic carbon (SOC) quantity, quality, and turnover are integral to soil health and often used as measures of soil health (Lal, 2016; Maharjan et al., 2020). Research in regenerative agriculture practices has demonstrated that several practices are key to optimizing SOC: practicing minimum or no tillage

Table 3. Use of environmental stewardship practices by surveyed growers.

Practice	*Organic Acres (n of 4 farmers surveyed)*	*Conventional Acres (n of 5 farmers surveyed)*
Buffer Strips	3/4	4/5
Fertilizer management (e.g. 4Rs, data enabled precision application)	3/4	5/5
No/minimum tillage	2/4	4/5
Cover Crops	4/4	5/5
Crop Rotation	3/4	4/5
Intercropping	0/4	0/5
Rotational grazing	1/4	1/5
Use of beneficial organisms	3/4	2/5
IPM principles (identifying, evaluating, preventing, acting, and monitoring pests)	4/4	5/5
Water use management	4/4	5/5
Natural habitat areas	4/4	5/5

(which can be enabled by both organic and conventional weed control), employing use of cover crops to keep the soil covered through the winter months, crop rotation, and addition of organic matter amendments such as manure or biochar (Lal, 2016). Currently, much research is focused on the association of these practices with carbon sequestration in order to combat climate change. The utility of this approach is still under discussion given the multitude of factors involved in the system (Giller et al., 2021). For example, carbon storage is highly dependent on the soil type and can reach saturation potential. In the larger scheme, the impact on greenhouse gas emissions from carbon storage in the soil of current agricultural lands may be small relative to land use change and other aspects of crop emission such as fertilizer use and irrigation. Nonetheless, outreach programs to train farmers, grants, and direct incentives such as government subsidies and private carbon markets are at various stages of development (Honeycutt et al., 2020; USDA, 2021). A key challenge in this process will be establishment of measurement, reporting, and verification to ensure that the desired outcome is met.

Several of these US-based growers thought that an environmental outcome-based regenerative agriculture program could be viable if the following criteria were met: flexibility and options to pick from in management practices that achieve the desired outcome, acknowledgement on a regional level of varying needs and practices (to acknowledge differences in pest pressures, soil types and other environmental factors), a clear list of certification requirements, a third-party verification system, and being tied to a premium. One grower pointed to water management programs in rice as an example of a system that met these requirements to build success. Growers acknowledged that soil health is of interest to the environmental community and consumers, but to become viable, there would need to be a clear indicator set like soil organic matter and an appropriate window of time (e.g. 5 years) to measure the change, and the other elements of data collection process, claim certification and mechanism for financial return established. One grower pointed out that most research on soil health has been conducted in the Midwest corn and soy belt, and data collection and practice recommendations may not easily transfer to other production environments. Another grower expressed that a carbon market may be the best proxy for many environmental indicators and that this represents a rare occasion where there is alignment in language and purpose between growers and ESG-minded investors (i.e. Environmental, Social and Governance). This grower felt that to be successful, a carbon market requires consumers and/or investors to pay, likely in the form of carbon credits, and will require the right sensing technology to assist measurement.

The authors note that in contrast, organic agriculture as defined in the U.S. by USDA is largely a process-based certification program rather than an outcome-based program. While the philosophy is based on promoting 'ecological balance,' there are many examples where organic processes are not consistently better in terms of environmental outcomes. Seufert and Ramankutty (2017) conducted a thorough assessment and found a high degree of variability in how organic performs compared to conventional agriculture. There were some circumstances where organic had clear benefits such as a positive influence on local biodiversity and high productivity for fodder, legumes, and perennials. There were some circumstances where there was equivocal or no benefit of organic compared to conventional practices (i.e. conventional practices were more beneficial) such as yield stability, also known as resilience, and greenhouse gas emissions per unit of food output. Use of non-synthetic pesticides is also not uniformly associated with beneficial environmental outcomes. Take the case of copper containing products such as copper sulfate, which is used to control various plant diseases. Repeated use of copper sulfate can result in soil accumulation of copper. At high levels in soil, copper can cause damage to crops through interveinal chlorosis and root damage and can impact soil earthworms and microorganism (Kühne et al., 2017; USDA AMS, 2015b).

In summary, regenerative agriculture models that combine recommended practices with a focus on desired outcomes may provide some flexibility for farmers and acknowledge that while certain practices may be shown to achieve a desired outcome, that may not be true in all situations.

Production and farm management

According to the survey by Mpanga et al. (2021), production challenges were the second most frequently reported issue for organic farmers. Growers in the current survey were asked to expound on challenges related to production as well as farm management.

Participants identified low yields, cost and availability of labor, larger investment of time and equipment, and management of isolation distances and reduced ability to expand acres (Table 2). In addition, fertilizer issues were a common theme amongst growers, citing cost, availability of manure, and substandard release characteristics relative to synthetic fertilizers.

Pest management was also cited as a major challenge (summarized in Table 2). Growers using organic production methods were queried on the type of interventions used to manage weeds, insects, and disease (summarized in Table 4). For weed control, tillage and mechanical weeding were most common. Lack of effectiveness of organic herbicides was mentioned by a current organic grower and a grower who identified this as a barrier to entry. Oils, crop rotation, and biological methods were used for insect control. Oils, biologicals, and copper-based fungicides were cited for disease control. Several growers discussed the need to select fields that are naturally low in certain insect and disease pressures for their organic fields. One grower stated, '*… we convert acres [to certified organic] based on low pest pressure … that approach is not always good for a particular [apple] variety*'. From this observation, the authors surmised that this phenomenon may be widespread and thus, not all acres under production could successfully grow crops organically. All growers in the survey maintain and follow an integrated pest management (IPM) plan on their farm. Growers discussed the limited set of tools, the need to 'get ahead' of any outbreaks to prevent major loss and frustration that non-selective organic pesticides can harm beneficial organisms.

To put these challenges in perspective, it is useful to review how pesticides are approved for use in organic agriculture. The National List of Allowed and Prohibited Substances identifies substances that can and cannot be used in organic crop and livestock production. In general, synthetic substances are prohibited for crop and livestock production unless specifically allowed and non-synthetic substances are allowed for crop and livestock production unless specifically prohibited (USDA AMS, 2024). The current list is available through the Code of Federal regulations (7CFR Part 205 Subpart G). Sewage sludge, irradiation, genetic engineering, and most synthetic fertilizers and pesticides may not be used. Permitted synthetic substances include soaps as animal repellent, copper sulfate and boric acid as insecticides and peracetic acid to control bacterial disease.

Regulation of Organic Approved Pesticides (OAPs) in the US is a three-step process that involves: (1) U.S. Environmental Protection Agency (EPA), (2) United States Department of Agriculture Agricultural Marketing Service (USDA-AMS) and (3) A certifying agent such as Organic Materials Review Institute (OMRI), the Washington State Dept. of Ag (WASDA), or Ecocert. EPA does not change their process of risk assessment or risk management of pesticides based on whether the pesticide qualifies as an OAP. However, many OAPs fall into specialized regulatory categories such as biopesticides, which require less study data and make use of literature summaries to request waivers from certain studies, can be registered more quickly, and often are exempt from the establishment of a Maximum Residue Level (MRL) (40 CFR 158.2). After a pesticide has received EPA approval, it must be approved by USDA-AMS to join the National List of Allowed and Prohibited Substances described above (7 CFR 205.6). It is important to note that joining this list not a statement or endorsement by USDA regarding product safety or nutrition; rather, the USDA organic label is a marketing statement (USDA AMS, 2012). The National List may be changed by the recommendation of the NOSB (7 USC 6518). The primary criteria for a material to be included on the National List is that the material must be consistent with organic farming, meaning that it is non-synthetic whenever possible (7 U.S.C 6504). As the USDA-AMS maintains a list of approved ingredients only and does not approve individual pesticides, it is the role of a materials agent to identify which pesticides meet the NOP standards and provide each approved product with a seal of approval. The seal that materials agents provide

Table 4. Types of pest control interventions used in organic production.

Weeds	*Insects*	*Disease*
Propene burners	Mating disruption through pheromones	Biologicals
Weed strips on ground	Insecticidal oils	Fatty acid soaps
Organic herbicides (e.g. Fatty acid herbicides)	Fatty acid soap	Crop oils
Light tillage	Predator release	Tactical removal
Electric arms	Biologicals, e.g. viruses engineered towards pest	Inoculums
Crop rotation	Crop rotation	Copper-based fungicides
Cover crops	Selecting fields with no natural pests to the crop	Choose fields with low or no disease pressure
Rotational grazing		
Mechanical/hand weeding		

gives confidence to organic farmers required to document all chemicals that are used on their farms, and the use of unapproved chemicals could cause them to lose their organic label (7 USC 6504).

As illustrated in the case studies, the process-based approach to allowing primarily non-synthetic chemicals creates substantial regulatory burden that limits adoption of organic farming. On the other hand, many useful practices are in place for pest management on organic farms that have broad applicability, i.e. the use of the PAMS strategy: prevention, avoidance, monitoring, and suppression (USDA AMS, 2015a). This strategy is also a key component of IPM. Prevention and avoidance include activities such as cleaning equipment to prevent spread between fields, using pest-free seeds and pest resistant varieties, crop rotation and refuge management, and managing irrigation to prevent situations where disease can develop (NRCS, 2010; North Central IPM Center, 2010). Monitoring includes scouting in the field and using models and weather forecasts to decide when to employ pest suppression strategies. Suppression includes use of cultural, mechanical, biological, and chemical control methods that reduce or eliminate a pest population (NRCS, 2010). This could include things like releasing predatory insects, laying down mulch to smother weeds, application of a naturally occurring microorganisms or insecticides derived from plants, or one of a few approved synthetic substances (USDA AMS, 2015a).

Like the example of soil health, the authors posit that regenerative agriculture may benefit from applying the concept of marrying recommended processes with desired outcomes to the topic of pest control. This concept is embedded in IPM, defined by USDA as: '… a sustainable, science-based, decision-making process that combines biological, cultural, physical, and chemical tools to identify, manage and reduce risk from pests and pest management tools and strategies in a way that minimizes overall economic, health, and environmental risks.' IPM is inclusive of managing insects, weeds, and disease and is built on the five-prong strategy of identifying, evaluating, preventing, taking action, and monitoring pests (Regional IPM Centers, 2022). This approach does not put process-limits on the use of pesticides. In fact, The Weed Science Society of America, the American Phytopathological Society, and the Plant-Insect Ecosystems Section of the Entomological Society of America issued a statement that pesticides are an important part of IPM and that restricting their use by considering them a 'last resort' or selecting only the 'least toxic pesticide' can result in a build-up of pests and reduce the overall options for control (WSSA, 2012). There are other examples of non-organic practices that reduce or even eradicate pests and enable area-wide pest suppression that benefits other producers within the area (Tabashnik et al., 2021; Dively et al., 2018). The food supply chain is working to support the IPM approach through training, measurement, and communication with stakeholders (TSC, 2021).

Growers in this survey indicated current use of IPM and fertilizer management practices, and willingness to adopt innovative tools and practices to improve farm management. Therefore, the authors conclude that regenerative agriculture definitions and programs could build on these concepts to expand uptake and place additional emphasis on measuring, evaluating and improving practices to achieve desired outcomes. Farm management improvements are likely to benefit the cited issues with labor as well.

Market access and profitability

The most common reason from those surveyed for growing certified organic was profitability, which is supported by consumer demand for organic products (Figure 1). Despite the equivalence in regulatory standards and clear articulation by USDA that certified organic is a marketing program, consumers do perceive a difference in safety between organic and conventionally produced foods. Funk and Kennedy (2016) pointed out that this difference is particularly strong in developed countries. In a survey, Boston consumers perceived relatively high risks associated with conventionally grown produce compared with other public health hazards such as mortality risk from motor vehicle accidents in the U.S. Over 90% of consumers surveyed perceived a reduction in pesticide residue risk associated with substituting organically grown produce for conventionally grown produce (Williams & Hammitt, 2001). The authors of that study found that distrust towards regulatory agencies contributed to a higher risk perception. Similarly, a study by the Center for Food Integrity (CFI, 2018) showed that American consumers view federal regulatory agencies such as the EPA most responsible for ensuring safe food, but they are only the eighth most trusted. A more recent ethnographic survey

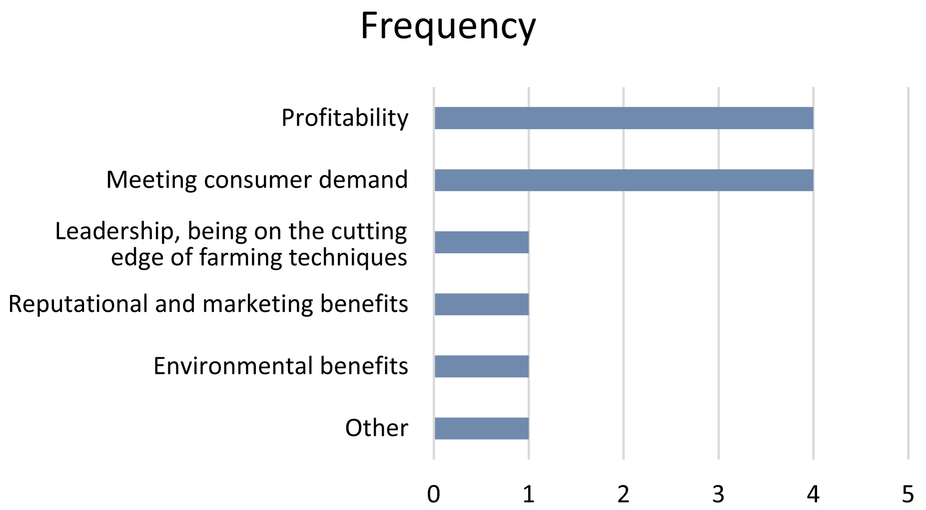

Figure 1. Reason for growing organic N = 4; Growers could select more than one reason. Other: Relationship management with product buyer; experimentation to understand impact of practices on yields and soil.

showed that online conversation about pesticides is strong with over 20 million consumers involved and expected to triple over the next two years (CFI, 2021). The study points to consumer concern about food safety and the environment, the belief that chemical use should be avoided, and that organic offers an alternative that reduces pesticide use.

In strong contrast to consumer perceptions, the majority of growers in this survey did not see organic as having strong cutting-edge leadership (i.e. using the most advanced techniques amongst peer group) or environmental benefits. Instead, one grower cited the need to grow organic to maintain successful relationships with product buyers that expected a mix of conventional and organic product.

In the Mpanga et al. study (2021), market access and price were identified as significant challenges for certified organic growers. Consistent with other reports, growers in the current survey discussed the challenges that organic production has lower marketable yield and requires more labor and equipment (Seufert et al., 2012; Seufert & Ramankutty, 2017; Meemken & Qaim, 2018). Some growers were able to manage this additional cost by securing contracts at a price premium. Others were dependent on market price at time of harvest. In both scenarios, growers identified significant risk to profitability when undertaking organic production. From this survey, specific challenges in the areas of cost and availability of labor, and the ability to secure price premiums to ensure profitability are major issues facing organic farmers. The authors surmised that these responses highlight the fact that livelihood is a significant component of sustainability for largeholder farmers, just as it is for smallholders.

The growers surveyed did not see the regenerative agriculture trends impacting organic significantly in the near term. They cited the value as a recognized certification to consumers and perceived health and environmental benefits of that certification. Growers felt that to enable growth in that market, some of the challenges identified in Table 2 should be addressed. One interesting insight from a grower in the survey was the idea that derogations to allow emergency use in pest control situations under an IPM plan could provide relief to certified organic growers in certain circumstances.

Growers were asked to comment on how they defined regenerative agriculture, whether creating an outcome-based program or certification is viable and the critical elements required to make such an approach attractive to growers. Growers generally found the term ‘regenerative agriculture’ to be ill-defined and defined differently across various stakeholders. One grower felt that it may provide more clarity and thus offer an improvement over the term ‘sustainability’. Personal definitions included: reducing degradation of soil; use of less inputs; less monoculture; improving soil fertility, biodiversity, and water cleanliness; and creating links between carbon in the soil and climate change. Growers emphasized that any system needs to recognize that grower profitability, economic survival, and durability of agriculture is essential. One grower stated,

> 'No one would say they disagree with these goals [i.e. of regenerative agriculture]. However, the number one goal of a farm is to survive and be profitable – so how do you incorporate these things and still maintain profitability?'. Another grower stated, ' … the economics needs to be there to support radical practice changes. There must be a mechanism to reward that process change.'

As described previously, several growers thought that an outcome-based regenerative agriculture program could be viable if it allows flexibility and options to pick from in management practices that achieve the desired outcome, acknowledges varying needs and practices, has a clear list of certification requirements, has a third-party verification system, and is tied to a premium. Growers believe that for the foreseeable future, both process-based organic and development of outcome-based programs will continue to co-exist. Whether the latter will develop into a cohesive definition of regenerative agriculture remains to be seen.

Conclusions and future implications

Organic has a long and rich history rooted in desire to promote ecological balance. While it has enjoyed robust growth in recent years, to be further successful or to facilitate introduction of the broader regenerative agriculture paradigm, there are several challenges that will need to be addressed. Profitability of the system is a key concern considering higher production costs combined with constraints that do not always deliver a guaranteed premium. A key production challenge is management of pests. Growers could benefit from more flexibility such as development of additional tools to combat difficult pests, ensuring multiple modes of action to prevent resistance and exploration of the use of derogations in concert with an IPM plan to deal with emergency situations. The current survey was small and focused on large acre growers. Additional research should be conducted to examine differences among farm types.

Environmental outcomes are important. It was clear from the present small survey that growers do not discriminate between production systems when adding in practices that have known benefits such as buffer strips, cover crops, and crop rotation. Given the serious concerns surrounding potential impact of climate change in the U.S. and impact on abiotic and biotic stressors like pest and disease pressure (Heisey & Day Rubenstein, 2015), it will be important both from a mitigation and adaptation perspective to continue to invest in research for new technologies and best practices.

Desired environmental outcomes may not always be met by relying too heavily on certification processes that are highly prescriptive but without clear evidence of leading to environmental benefits. New paradigms like regenerative agriculture may help move more of agriculture towards these outcomes. This mindset will be important to continue to produce enough food to feed our communities using optimum resources and continue improving environmental outcomes and soil health.

For a new paradigm to be successful, it will require flexibility and options to pick from in management practices that achieve the desired outcome, acknowledgement on a regional level of varying needs and practices, a clear list of certification requirements, a third-party verification system, and should be tied to a premium to reward the grower for the practices.

Consumers should have confidence in the safety of their food regardless of type of pesticides used given the robust nature of the pesticide review and registration process in the U.S. for organic and conventional pesticides. Additional opportunity exists to research communication strategies to build confidence in the U.S. food system.

Agriculture will continue to improve in its ability to provide sufficient nutritious food while meeting local and global environmental goals. These approaches come with inherent complexity that will need to be addressed through additional research, outreach to growers and consumers alike and supportive policy.

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Conflict of interest

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