INTERNATIONAL JOURNAL OF AGRICULTURAL SUSTAINABILITY
https://doi.org/10.1080/14735903.2022.2056997

Improving sustainable agriculture promotion: an explorative analysis of NRCS assistance programs and farmer perspectives

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ABSTRACT

Unsustainable agriculture practices are undermining the world's future ability to reliably produce food. Assistance programmes, such as those offered by the Natural Resource Conservation Service (NRCS) of the United States, can increase the uptake of sustainable practices, yet implementation of these alternatives in the US remains discouragingly limited. In this context, we used an interdisciplinary approach involving quantitative and qualitative data to assess the current efficacy of NRCS assistance programmes and identify areas for improvement. To do so, we first analyzed national reports of NRCS expenditures and acres treated over the last 15 years and then distributed an explorative survey to farmers and ranchers throughout Utah state. Our NRCS programme analysis suggested that historical increases in expenditures have been ineffective at increasing the number of acres treated. The survey responses indicated that both financial and non-financial factors were influential in farmer decisions. Farmers that assigned a high importance to sustainable practices were motivated by public perception and environmental stewardship while those that assigned a moderate importance were motivated by the potential return on investment. Overall, participants in NRCS programs reported more positive outcomes than expected by non-participants. We hope the findings from this study can guide future research and inform efforts to improve NRCS assistance programmes in Utah and other regions in the US and elsewhere.

KEYWORDS

sustainable agriculture; assistance programmes; NRCS; farmer perspectives; survey

1. Introduction

Sustainable intensification of agriculture is one of the most pressing and formidable global challenges facing humankind today. As a result of their negative impacts, unsustainable agricultural techniques are reducing present and future crop yields, human wellbeing, and ecosystem health worldwide (Albornoz, 2016; Bennett et al., 2001; Karlen & Rice, 2015; Lal, 1997; Maharjan et al., 2020; Woźniak, 2019). Sustainable production practices provide a critical opportunity to increase the long-term viability of the world's food systems. While many definitions of sustainable agriculture exist, we have adopted the following

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Supplemental data for this article can be accessed online at https://doi.org/10.1080/14735903.2022.2056997.

Table 1. List of Sustainable Practices Included in Survey.

Crop-Related Practices		Livestock-Related Practices
Agroforestry	Riparian Buffer Strips	Manure Recycling
Cover Crops	Rotating Crops	Natural Calving Season
Integrated Pest Management	Selling Directly to Consumers	Precision Irrigation
Intercropping	Strip Cropping	Riparian Buffer Strips
Precision Fertilizer Application	Trap Crops	Rotational/ Controlled Grazing
Precision Irrigation	Wildlife Habitat Management	Selling Directly to Consumers
Reduced/No-Tillage		Wildlife Habitat Management
		Winter Grazing

comprehensive definition: 'A sustainable food and agriculture [practice] is one which is environmentally sound, economically viable, socially responsible, non-exploitative, and which serves as the foundation for future generations' (Allen et al., 1991). Consistent with this definition, sustainable agriculture practices preserve or even enhance the ability of future generations to produce food and other goods (de Vrese et al., 2018; Kassam et al., 2009; Piazza et al., 2020; Pretty et al., 2006; Shrestha et al., 2020; Zhang et al., 2015). Table 1 lists agricultural practices that are widely recommended both by the scientific literature and conservation organizations as meeting the definition of Allen et al.

Unfortunately, implementation of sustainable agriculture methods throughout the United States remains discouragingly limited (Foley et al., 2011; Gerber et al., 2016; Hansen et al., 2012; Rodriguez et al., 2008; Sabo et al., 2021; Sabo et al., 2021; Shrestha et al., 2020; USDA NASS, 2019). Others have even gone so far as to claim that the widespread utilization of unsustainable conventional agriculture practices in the US food system 'represents one of the worst-case examples of the pitfalls of industrial agriculture' (Horrigan et al., 2002). In 2018, the Food Sustainability Index ranked the agricultural sustainability of 67 countries based on indicators related to land use, water use, and emissions. The US ranked in the 50th percentile of all included countries and the 37th percentile of the high income nations (Barilla Centre for Food & Nutrition, 2018). This shortcoming of the United States is especially unfortunate considering its role as an agricultural power in the global market (Dées & Saint-Guilhem, 2011; Veeck et al., 2020).

Many factors likely contribute to the somewhat tepid adoption of sustainable agriculture by producers in the US and elsewhere. A wide variety of factors influence individual farmer's decision to implement a given practice and, as such, it is a major challenge for farmers to simultaneously optimize the profitability, productivity, and sustainability of their operations (Bopp et al., 2019; Corselius et al., 2003; Epanchin-Niell et al., 2022; Ward et al., 2018; Zhang et al., 2015). As a result of these contrasting priorities, it is unsurprising that profitability and productivity frequently trump environmental sustainability as top priorities. Furthermore, the effects of sustainable agriculture practices on crop yields and operation profitability—two factors of extreme importance to growers—vary widely based on individual circumstances. Depending on the crop type, climate, and other factors, sustainable practices may decrease or increase yields compared to more conventional techniques (Allam et al., 2021; Laborde et al., 2020; Marcillo & Miguez, 2017; Pittelkow et al., 2015; Pittelkow et al., 2015). Such variability can make it difficult for producers to predict how a given technique will affect the viability of their operation.

To promote the adoption of sustainable agriculture practices, many local to international organizations rely on incentives, education, and assistance programmes (Lichtenberg, 2004; Tilman et al., 2002). The Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) is one such organization that encourages voluntary and incentive-based conservation practices at a local level through field offices in nearly every county in the US. NRCS programmes offer three main categories of assistance: (1) *technical assistance* in the form of scientific expertise, natural resource data, tools, and technology that help producers develop and implement conservation plans, (2) *financial assistance* in the form of cost-share, easement, or rental payments that assist the producers in paying the costs of implementing conservation measures, and (3) *reimbursable funds* that are administered by the NRCS to fund technical or financial assistance provided by another federal agency.

The limited implementation rates of sustainable agriculture practices brings into question the effectiveness of NRCS assistance programmes. In 2002 the USDA created the Conservation Effects Assessment Project (CEAP) in an attempt to track the environmental impacts of NRCS programmes on

croplands, grazing lands, wetlands, and wildlife (Briske et al., 2017; Duriancik et al., 2008). However, the only published regional and national level cropland assessments produced by CEAP are based on data from 2003-2006, meaning that the existing information is likely no longer representative of current conditions (USDA NRCS, 2017a; USDA NRCS, 2017b; USDA NRCS, 2017c; USDA NRCS, 2017d). In 2007, an assessment of rangeland conservation practices was initiated by CEAP, but the synthesis was unable to document conservation benefits, likely due to the absence of protocols to account for rangeland conservation outcomes (Briske, 2011; Briske et al., 2017). More recently, Briske et al. (2017) found that NRCS conservation programmes were 'insufficiently designed to support efficient, cost-effective, and accountable conservation programmes.'

In this paper, we attempt to identify specific ways in which the US can better motivate and assist growers in the implementation of sustainable agriculture practices. To do so, we carried out two related research activities: First, we assessed the current efficacy of national sustainable agriculture assistance programmes by analyzing reported expenditures and acres treated. Second, using Utah as a case study, we developed and distributed an explorative questionnaire to farmers throughout the state to assess their attitudes and behaviours related to sustainable practices and NRCS assistance programmes (Dessart et al., 2021). We hypothesized that while farmers face financial barriers to implementing more sustainable techniques, other non-financial obstacles would also have a significant influence on a farmer's decision to implement or not implement sustainable practices. This hypothesis is consistent with the findings of previous studies carried out in other regions of the US (Baumgart-Getz et al., 2012; Carolan, 2005; O'Connell et al., 2015; D. A. Weisberger et al., 2021). By identifying these previously unaddressed obstacles, we expected to find opportunities to increase the implementation of sustainable practices in Utah and learn lessons that could be applied elsewhere, thus informing the effort to transition to more sustainable food systems.

We propose that the primary function of an assistance programme, such as those associated with the NRCS, is to help individuals overcome specific barriers on the path to implementing sustainable practices (Figure 1). As individual producers seek to increase the adoption of sustainable practices, intermediary steps must be taken. For example, farmers must feel motivated to implement sustainable practices, be aware of specific practices, and then be able to implement them. However, any number of obstacles can interrupt this transition at multiple points. The various types of NRCS assistance programmes can help farmers to understand the why, what, and how of transitioning to more sustainable techniques, as well as providing them with the needed resources to do so. As this process is followed for many individual operations, the end result is a individual and cultural shift to more sustainable agricultural systems.

2. Materials and methods

2.1. NRCS report analysis

To assess the effectiveness of NRCS assistance programmes, we calculated overall expenditures and acres treated by the NRCS for the last 15 years, as well as the cost per acre treated. The data for these calculations was accessed through publicly available NRCS conservation programme reports which are published annually (USDA, 2021a). 2019 was the most recent year available when we performed our analysis and visualization. We calculated temporal trends in expenditures, acres treated, and cost per acre using simple linear regression and reported the correlation coefficients.

2.2. Survey design and distribution

We distributed an exploratory survey to farmers and ranchers throughout the state of Utah in order to assess their perspectives on sustainable practices and assistance programmes and identify potential areas of improvement for NRCS assistance programmes. The survey, which was developed and distributed using the Qualtrics XM online platform (Qualtrics, 2020), asked each respondent up to 29 questions and was estimated to take roughly 10 minutes to complete. Many of the survey questions employed a 0-to-10 Likert scale that allowed respondents to provide their opinion in a quantified manner (Joshi et al., 2015). An archived version of the survey is available at https://dataverse.harvard.edu/dataverse/byusustainableagsurvey.

Utah was selected as the location of this case study because it is representative of the irrigated dryland agriculture common in the western U.S. and because of existing networks between the researchers and local NRCS and USDA offices. Furthermore, the

Figure 1. Framework illustrating the proposed role of NRCS assistance programmes in overcoming the barriers in transitioning to sustainable practices.

majority of studies regarding farmer perspectives have been conducted in the eastern or midwestern United States, with fewer occurring in the western US. Utah state is located in the Mountain West region of the United States and features highly variable elevation, precipitation, temperature, and growing seasons. The overall climate is semi-arid with long, hot summers and short, cold winters. Utah's agriculture is dominated by livestock, especially cattle, though crops such as hay or grains also make up a significant proportion of the total market value. Over recent decades, the western US has been plagued by a megadrought, with 2020 being the driest year on record for several western states, including Utah (NOAA, 2021; Williams et al., 2020). This trend of drought and high temperatures has had a strongly negative impact on agriculture in the western US, particularly in terms of water scarcity limiting irrigation (Howitt et al., 2015, p. 201). While each state is unique, identifying ways that Utah's NRCS programmes can become more effective can reveal insights that can be applied to other western states. Additional information on the agricultural profile and NRCS assistance programmes of Utah specifically is available in the supplementary information.

The survey was distributed to farmers and ranchers throughout Utah state using a wide variety of channels to minimize selection bias (i.e. organization e-newsletters, print newsletters, farmers markets, social media groups, and personal invitations). The complete list of organizations and other channels used to distribute the survey can be found in the supplementary information. Although it is difficult to estimate the exact number of people that received the opportunity to participate in the survey, several of the distribution channels included 2,000-3,000 members. Thus, it is reasonable to assume that the opportunity to participate in the survey reached a sufficiently large group of potential respondents. To increase participation in the survey, we offered participants that completed the survey the opportunity to enter a drawing for a $100 prize. Despite this measure, the survey response rate remained limited as will be discussed later.

Once survey response collection was finished, survey responses were standardized, classified according to the USDA definition of a farm, and analyzed statistically. Because previous research indicates that the size and type of agricultural operation influences perception and implementation of sustainable practices (Knutson et al., 2011; Lubell et al., 2011; Meijer et al., 2015; Saltiel et al., 1994), we classified all respondents according to the USDA definition of a farm before analysis. The USDA defines a farm as any operation with the potential to produce at least $1,000 worth of agricultural goods in a typical year. The USDA relies on a point value system to assign a specific number of points to each operation based on crop acreage and livestock inventory to determine if it qualifies for farm status (O'Donoghue et al., 2009). Due to the confidentiality of the point system documents, the analysis for this project used the Utah Department of Agriculture and Food's (UDAF) 2019 annual summary report to estimate crop or livestock values for each survey response (Hilton & Gentillon, 2019). This estimated value of the goods produced by an operation was used to determine if it was considered a farm, non-farm, or unknown according to the USDA definition for our survey. A survey response

was classified as unknown when it did not provide enough information to estimate the worth of the producers' agricultural goods. All subsequent analyses of survey responses considered only those responses that were considered farms according to the USDA definition. We used the statistical software package R to test for differences among groups with analysis of variance (ANOVA) as well as produce all plots (R Core Team, 2018).

Questions in the survey focused on assessing the implementation rates of sustainable practices, the factors and obstacles that drive or diminish implementation, the perspectives of producers regarding sustainable techniques, and the respondent's awareness of and participation in NRCS assistance programmes:

2.2.1. Implementation status

The survey asked respondents to report the implementation status of sustainable practices at their operation. To do so, participants sorted a list of practices relevant to their operation into four categories: *Already implemented, Not currently implemented but would consider implementing, Not currently implemented and would NOT consider implementing,* and *Not applicable to my operation.* This sorting of practices was intended to provide a qualitative metric of the sustainability of each respondents' operation (Nziguheba et al., 2021) as well as information on the implementation rates of each practice included in the survey. The list of practices included in the survey is the same as that presented in Table 1.

To assess how efficiently each practice might be promoted by NRCS assistance programmes, we assigned each practice a ratio based on how frequently it was sorted into each of the implementation status categories. The *Already implemented, Would NOT consider implementing,* or *Not applicable to my operation* categories represent circumstances when increasing the implementation of a practice would be difficult or impossible. The *Would consider implementing* category, however, represents circumstances where this might be comparatively easier. It is thus helpful to view the sorting of these practices in terms of the ratio of respondents that sorted the practice into either the *Already implemented, Would NOT consider implementing,* or *Not applicable to my operation* versus the number of respondents who sorted the practice into the *Would consider implementing* category (ANN:W ratio). Practices with a high ANN:W ratio would represent a more difficult target for increasing implementation due to increased physical or attitudinal barriers relative to a practice with a lower ANN:W ratio. While the ANN:W ratio does not reflect the important individual factors and circumstances that would lead a farmer to implement a practice, it can give insights about general trends among farmers in Utah.

After sorting the practices, the respondents were asked further questions about a single practice they had sorted into each category (other than the *Not applicable to my operation category).* Farmers were asked to report on how a sustainable practice they were already implementing had impacted the health, productivity, and value of their crops as well as the simplicity, costs, and profitability of their operation as a whole. They were similarly asked how they expected a sustainable practice they would consider implementing and one they would not consider implementing to impact these same metrics. This allowed us to quantify how farmers perceived the impacts of sustainable agriculture practices pre- and post-implementation.

2.2.2. Implementation factors and obstacles

To test our hypothesis, the survey asked participants to identify the primary factors behind their decision to implement or not implement certain sustainable practices. This included asking about what had motivated them to implement sustainable practices in the past as well as what barriers they faced to implement additional practices. Farmers were also asked to assess how effective each assistance type offered by the NRCS assistance programmes would be in motivating/assisting them to implement a sustainable practice they would and would not consider implementing.

2.2.3. Farmer perspectives

The survey sought to understand how farmers perceive the sustainability of their own operation as well as sustainable practices in general. In an attempt to measure how accurately farmers perceive the sustainability of their operation, respondents were asked to rate the current sustainability of their operation. This was done after defining sustainability for the farmers but before having them sort the list of sustainable practices to avoid influencing how they perceived their operation. This self-rating was then analyzed in conjunction with how the respondent sorted the list of practices according to their implementation status to reveal the grower's sustainability self-awareness. To assess the overall attitudes

of farmers regarding sustainable agriculture practices, farmers were asked to assign an importance to the implementation of the sustainable practices listed in Table 1 and then given the opportunity to explain their answers.

2.2.4. Knowledge of NRCS programmes

To identify any disconnects between farmers and NRCS assistance programmes, the survey provided participants with a list of 8 NRCS assistance programmes and asked them to report which programmes they were aware of and which they had participated in. The list of NRCS programmes included all programmes whose expenditures over the last five years were more than 0.5% of the combined expenditures of all Utah NRCS programmes over the same period. Two non-existent programmes were also included to act as controls. The list of included programmes can be viewed in the supplementary information. If farmers indicated participation in one or more NRCS programmes, they were asked what type of assistance they received.

3. Results

3.1. NRCS report analysis

We found that over the last twenty years, NRCS expenditures have steadily increased while the number of acres impacted by these expenditures has not. During the 2020 fiscal year, the NRCS reported 6.2 billion dollars of total obligations (binding agreements that will result in immediate or future NRCS expenditures), the highest amount recorded since the Foundation Financial Information System (FFIS) began to track the obligations in 2002 (USDA, 2021a). During that period, total NRCS obligations have grown at an average rate of approximately 173.9 million dollars per year ($R = 0.928$, $p = 1.06 \times 10^{-8}$), with the obligations corresponding to financial assistance driving that growth. This represents a total increase of 226% from 2002 to 2020, which greatly outpaces the total inflation of 43.9% over the same time frame (U.S. Bureau of Labour Statistics, 2021). In contrast, the total number of acres treated by NRCS programmes has remained relatively unchanged over the last 15 years ($R = 0.133$, $p = 0.623$). As a result, the ratio of obligation dollars to acres implementing conservation practices has grown at a rate of 4.07 dollars each year ($R = 0.850$, $p = 3.07 \times 10^{-5}$). These insights suggest that increasing NRCS expenditures has not efficiently increased the number of acres implementing conservation measures. Figure S1 in the supplementary information presents these findings visually.

3.2. Survey responses

Survey participation was limited. The survey received 129 total responses from August 5th, 2020 to October 30th, 2020, of which 31 responses qualified as farms according to the USDA definition. Of the other responses, 20 responses were considered non-farm responses, 6 respondents did not provide enough information to be classified as a farm or non-farm, and 72 responses were largely or entirely blank. The median time to complete the survey was 12.3 minutes. Based on the participant's self-reported demographics, our respondents generally matched the actual demographic of Utah farmers and ranchers according to the 2017 Utah Ag Census with some exceptions. Table 2 shows the exact comparison.

The relatively small sample size of survey responses (0.17% of the number of farms counted by the 2017 Utah Census of Agriculture) suggests that further research is needed to confirm the results and how they may be applied to other locations outside of Utah. We were encouraged, however, by how well the sample matched the 2017 census in terms of the metrics in Table 2, suggesting that the survey did still fulfil its exploratory purpose. One significant difference between the two columns was that the survey sample had a much higher

Table 2. Comparison of 2017 Utah Ag Census and Survey Sample.

Metric	2017 Utah Ag Census	Survey Sample[a]
Age	<35: 9% 35–64: 59% 65+: 32%	<30: 26% 30–64: 74% 65+: 0%
Sex	64% Male, 36% Female	84% Male, 16% Female
Top Counties (by acres)	Uintah, San Juan, Box Elder	Box Elder, Sanpete, Juab
Average Operation Size (acres)	587	405
Primary Crops (by acres)	Forage, Wheat, Corn	Forage, Wheat, Corn
Primary Livestock (by count)	Chickens, Turkeys, Cattle/Calves	Cattle/Calves, Goats, Sheep
% Hire Farm Labour	25%	32%
% Family Farms	95%	84%
% New Farmers	28%	19%
% Sell Directly to Consumers	7%	64%

a. These statistics represent only the survey responses that were considered farms according to the USDA definition.

percentage that reported selling directly to consumers than the census did. This could potentially indicate that the sample represents a group of farmers that was already implementing that sustainable technique, and likely other techniques, more than the average Utah producer. This would be unsurprising as it is commonly understood that the salience of a survey topic to an individual is a key determinant in how likely they are to participate (Dillman & Carley-Baxter, 2000). An alternate explanation is that a portion of the farmers in our sample believed that they were selling directly to consumers when the requirements of the 2017 census concluded that they were not (or perhaps were not selling a large enough portion of their products to consumers to meet the USDA's definition). This would be consistent with previous findings that producers and experts frequently understand sustainable practices and what is included in them differently (van Hulst et al., 2020; Veisi et al., 2021). The specific practice of selling directly to consumers was one of the few practices that were not defined in the survey, and it is possible that the clarifying definitions provided for the other practices helped to avoid similar discrepancies (Bossange et al., 2016).

3.2.1. Implementation status of sustainable practices

See Figure 2 for the distribution of how sustainable practices were sorted by the respondents and Table 3 for the ANN:W ratios of each practice, ordered from lowest to highest. 6 farmers sorted only crop-related practices, 7 farmers sorted only livestock-related practices, and 18 farmers sorted both crop- and livestock-related practices. It should be noted that the practices that were sorted both by primarily crop-based and primarily livestock-based operations (such as wildlife habitat management or riparian buffer strips) received different ANN:W ratios depending on the operation type. This is not surprising since operations focused on crops have drastically different needs and priorities than those focused on livestock, and vice versa.

Farmers who were already implementing sustainable practices on average viewed the resulting impacts as more positive than both those who would and would not consider implementing them for almost every metric (Figure 3). For example, on a scale of 0–10 with 10 being greatly increased and 0 being greatly decreased, farmers who would not consider implementing a practice expected the sustainable practices to have an average impact of 4.57 on the health of their crops, while farmers who would consider implementing them expected an average impact of 6.52 on crop health. In fact, the farmers who had already implemented the practices reported an impact of 6.9 on the health of their crops. While farmers observed a slight increase in the costs of their operations after implementing any given sustainable practice, they reported a larger increase in crop productivity, health, and value, resulting in an overall observed increase in operation profitability. Although these trends represent an average that does not distinguish between individual practices or farmers, the general trend of farmers reporting better results from implementing sustainable agriculture practices than expected is encouraging.

3.2.2. Implementation factors and obstacles

The survey responses indicated that while certain factors play a bigger role than others in a farmer's decision to implement a practice or not, many factors are involved. Figure 4 (A) shows the distribution of factors that led to a practice's implementation while (B) shows the obstacles to implementation when farmers would consider or would not consider implementing a practice.

Two of the three most selected reasons for implementing a sustainable practice (long-term sustainability of the operation; prior personal experience with the practice) were non-financial. Similarly, two of the four most common barriers to implementing a practice that the farmers would consider implementing (expected increase in complexity; lack of expertise or experience with the practice) and three of the five most common barriers for practices they would not consider implementing (lack of expertise or experience with the practice; lack of information on assistance programmes; no need to implement) were non-financial. This confirms our hypothesis that non-financial factors represent major motivators and obstacles in the decision of a producer to implement or not implement a given practice.

Furthermore, we observed that even the less-frequently selected factors and obstacles still appeared in a significant number of responses. Indeed, the survey revealed a wide variety and distribution of reasons for implementing or not implementing each practice. This was especially true for the reasons that farmers would not consider implementing certain practices. However, even when answering about the practices they had already implemented or would

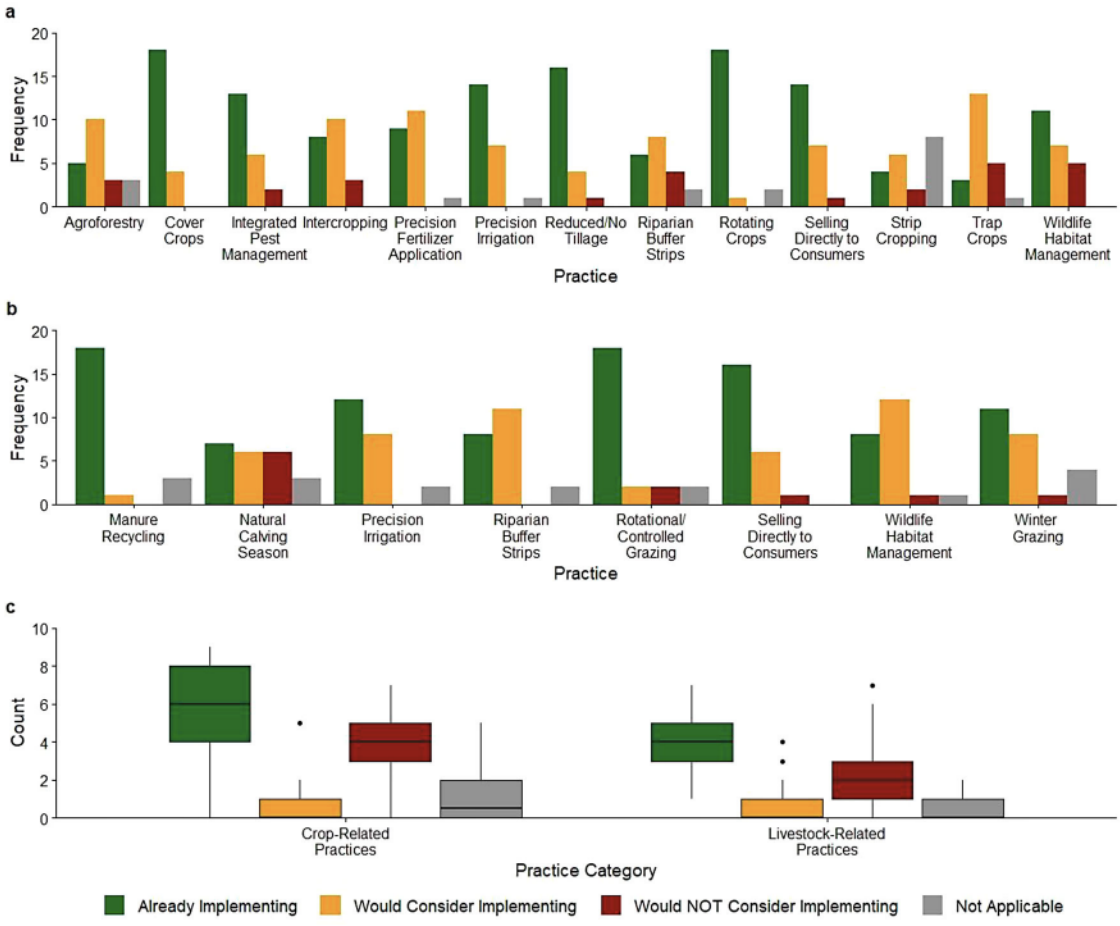

Figure 2. Shows how frequently each **(a)** crop-related practice and **(b)** livestock-related practice was sorted into the four categories of implementation status. **(c)** Shows the distribution of how many practices each respondent sorted into each implementation status.

consider implementing, a wide distribution of reasons was given by farmers. This suggests that instead of a few factors or barriers dominating a farmer's decision to implement a practice or not, many considerations come into play.

Despite the wide distribution of factors and obstacles affecting implementation decisions, including non-financial reasons, farmers identified financial assistance to be what they perceived as the most motivating form of assistance for practices they would and would not consider implementing. For practices they would consider implementing, producers on average ranked the effectiveness of financial assistance as 7.14 out of 10 (std = 3.19), with 10 being extremely effective. Scientific assistance received an average ranking of 6.41 (std = 3.29), while equipment assistance received an average ranking of 6.28 (std = 2.86). For practices they would not consider implementing, financial, scientific, and equipment assistance received rankings of 4.71 (std = 3.84), 3.21 (std = 3.21), and 3.64 (std = 3.54), respectively.

3.2.3. Farmer perspectives

When asked about the sustainability of their own operation, every farmer ranked their farm favourably. Figure 5 (A) shows the exact distribution. 58.06% of farmers strongly agreed that their operation was in line with the principle of agricultural stewardship, while 38.71% agreed, and 3.23% somewhat agreed. An ANOVA analysis showed no statistically significant difference in how farmers perceived the sustainability of their operation based on sex (df = 1, F = 1.177, p = 0.287), age (df = 4, F = 0.428, p = 0.787), education (df

Table 3. ANN:W Ratios of Sorted Practices.

Crop-Related Practices					
Practice	Respondents Already Implementing	Respondents That Would Consider Implementing	Respondents That Would NOT Consider Implementing	Respondents for Whom Not Applicable	ANN:W Ratio
Trap Crops	3	13	5	1	0.692
Precision Fertilizer Application	9	11	0	1	0.909
Agroforestry	5	10	3	3	1.100
Intercropping	8	10	3	0	1.100
Riparian Buffer Strips	6	8	4	2	1.500
Precision Irrigation	14	7	0	1	2.143
Selling Directly to Consumers	14	7	1	0	2.143
Wildlife Habitat Management	11	7	5	0	2.286
Strip Cropping	4	6	2	8	2.333
Integrated Pest Management	13	6	2	0	2.500
Reduced/No Tillage	16	4	1	0	4.250
Cover Crops	18	4	0	0	4.500
Rotating Crops	18	1	0	2	20.000
Livestock-Related Practices					
Practice	Respondents That Already Implementing	Respondents That Would Consider Implementing	Respondents That Would NOT Consider Implementing	Respondents That Not Applicable	ANN:W Ratio
Wildlife Habitat Management	8	12	1	1	0.833
Riparian Buffer Strips	8	11	0	2	0.909
Precision Irrigation	12	8	0	2	1.750
Winter Grazing	11	8	1	4	2.000
Natural Calving Season	7	6	6	3	2.667
Selling Directly to Consumers	16	6	1	0	2.833
Rotational/ Controlled Grazing	18	2	2	2	11.000
Manure Recycling	18	1	0	3	21.000

$= 5, F = 0.842, p = 0.533$), political affiliation ($df = 5, F = 1.097, p = 0.389$), or organization ($df = 7, F = 0.541, p = 0.793$). Interestingly, no significant correlation existed between a farmer's ranking of the sustainability of their operation and the number of sustainable practices they were already implementing ($R = -0.29, p = 0.11$).

The majority of farmers assigned a high importance to implementing sustainable agriculture practices. The average farmer assigned an importance of 8.23 out of 10 (with 10 being most important) to sustainable practices with a standard deviation of 1.93. An ANOVA analysis revealed no statistically significant difference in the importance given to sustainable practices by a farmer as a result of sex ($df = 1, F = 2.951, p = 0.0969$), age ($df = 4, F = 1.24, p = 0.32$), highest education level achieved ($df = 5, F = 0.517, p = 0.761$), political affiliation ($df = 5, F = 2.011, p = 0.117$), or the organization through which they received the survey link ($df = 7, F = 0.847, p = 0.564$). No statistically significant relationship was observed between the importance a farmer gave to sustainable practices and the number of practices they were already implementing ($R = 0.12, p = 0.51$), would consider implementing ($R = -0.26, p = 0.16$), would not consider implementing ($R = -0.27, p = 0.15$), or believed did not apply to their operation ($R = 0.16, p = 0.4$). Figure 5 (B) shows the distribution of the rankings given by the farmers.

Interesting patterns existed between the ranking given by a farmer and the reason they

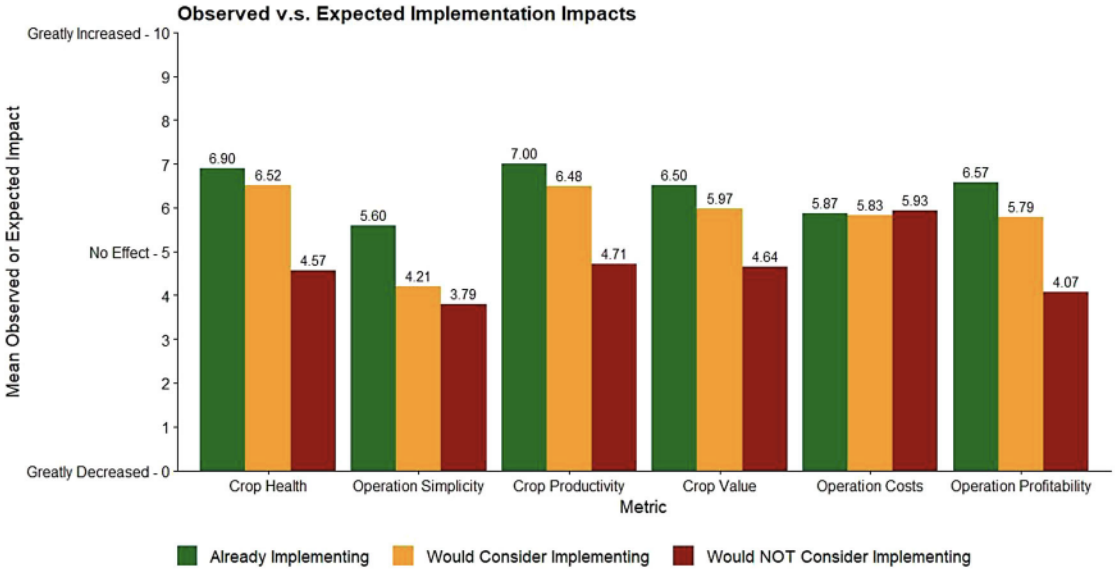

Figure 3. Compares the average expected impacts of implementing a given sustainable practice by farmers who have yet to do so to the actual impacts observed by farmers who had already done so.

gave for that ranking. The farmers who assigned a high importance (between 8 and 10) to sustainable practices frequently focused on environmental sustainability and public perception as the reasons for this high importance. 64% of the comments made by farmers that assigned a high importance to sustainable agriculture mentioned environmental sustainability while 21% mentioned public perception. The following quotations are representative of the comments for this high-importance group:

> 'In order to continue producing food for my community, and for future generations to do the same, the soil has to be healthy.' (Male, age 41-50, Livestock-based operation)

> 'There are a lot of people watching what we do, and we need to do our best at what we're doing.' (Male, age 51-60, Livestock-based operation)

> 'The eyes of the public are on us and we need to remember this. They, on the other hand, need to understand that we make a living off the land and so the proper farming techniques and husbandry practices are important to us too. You can't make a living if you fail to plan.' (Male, age 51-60, Mix of crops and livestock operation)

In comparison to the motives of the high importance group of farmers, farmers who assigned a moderate importance (between 5 and 7) to sustainable practices frequently explained that the return on investment of such practices was the key determinant for whether a practice should be implemented or not. 50% of the comments made by farmers that assigned a moderate importance to sustainable practices mentioned the profitability of their operation as a deciding factor. Representative quotations for this group are as follows:

> 'It is important as long as its cost and return are afforded.' (Male, age 41-50, Mix of crops and livestock operation)

> '*Time and money*' (Male, age 51-60, Mix of crops and livestock operation)

> '*Cost of return on the investment.*'(Male, age 41-50, Mix of crops and livestock operation)

Unfortunately, the survey revealed little about farmers that assigned neither a high nor moderate importance to sustainable practices. Because only one respondent assigned an importance less than 5 to sustainable practices and left no explanation as to why, it remains unclear how the factors that motivate those farmers who would assign a low, or even no, importance to sustainable practices might compare to those farmers in the high or moderate importance group.

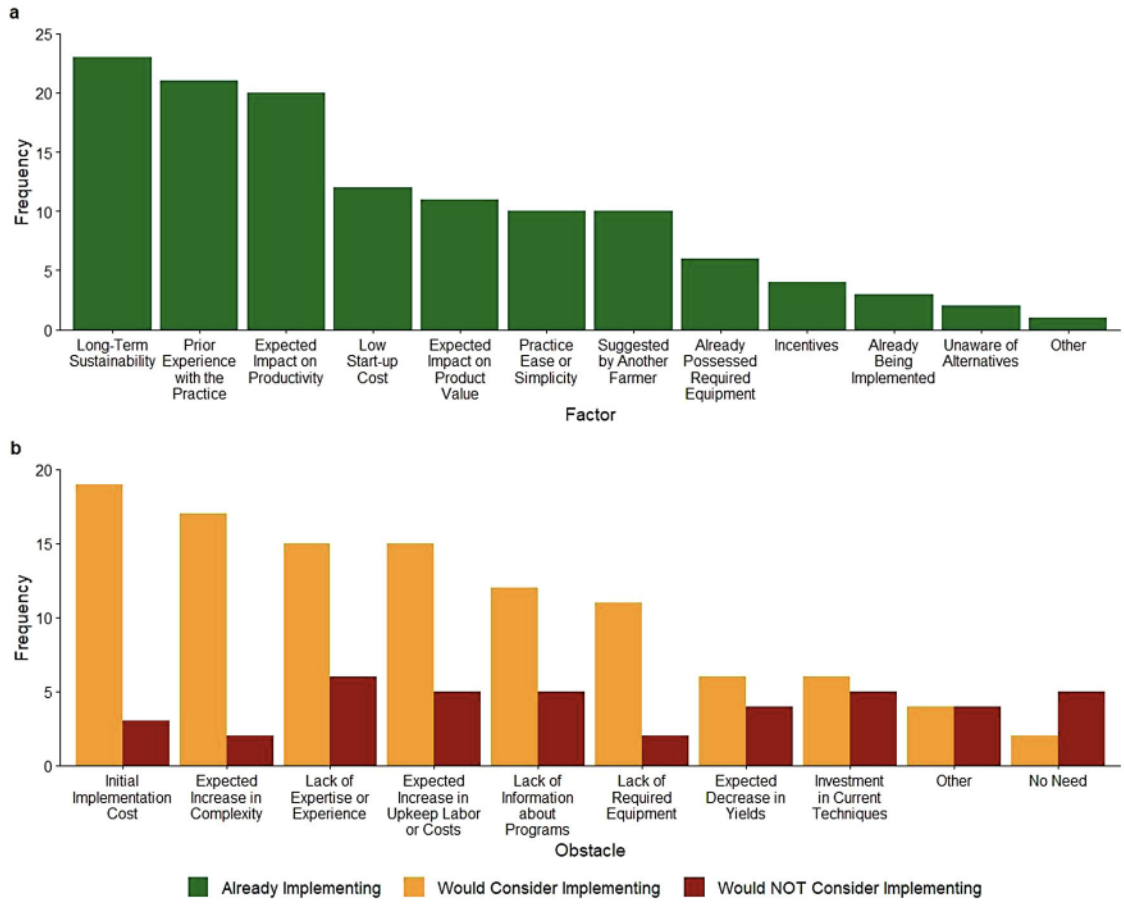

Figure 4. Shows the frequency with which farmers identified various **(a)** factors as leading them to implement a given sustainable practice or **(b)** specific obstacles as preventing them from implementing a given sustainable practice.

3.2.4. Knowledge of NRCS programmes

Every NRCS programme listed as part of the survey had at least one participant indicate that they were aware of the programme, though the number of farmers that indicated awareness of, or participation in, each programme varied. Respondents indicated awareness of 3.84 programmes on average with a standard deviation of 3.00 programmes. The Conservation Stewardship Programme (CSP) had the highest rate of farmer awareness at 67.74%, followed by the Environmental Quality Incentives Programme (EQIP) at 61.29%, and the Agricultural Conservation Easement Programme (ACEP) at 51.61%. 19.35% and 9.68% of farmers indicated awareness of the two non-existent programmes included as controls. The average famer reported participating in 1.61 NRCS programmes (std = 1.36) and 77.42% of farmers had participated in at least one programme. The programme with the highest rate of participation was CSP at 41.94% of farmers, with EQIP following at 35.48%. While some farmers did indicate that they were aware of the two fake control programmes, we were not as concerned with this as we were about farmers falsely indicating participation in nonexistent programmes. While this too, did occur, the percentage of farmers that indicated participation in these control programmes was small enough (3.23%) that we were not concerned about it negatively influencing the data.

The farmers indicated with their responses that financial assistance was the most common form of participation in NRCS programmes. 70.58% of farmers that had participated in an NRCS assistance programme indicated that they had received financial assistance. Equipment or technology

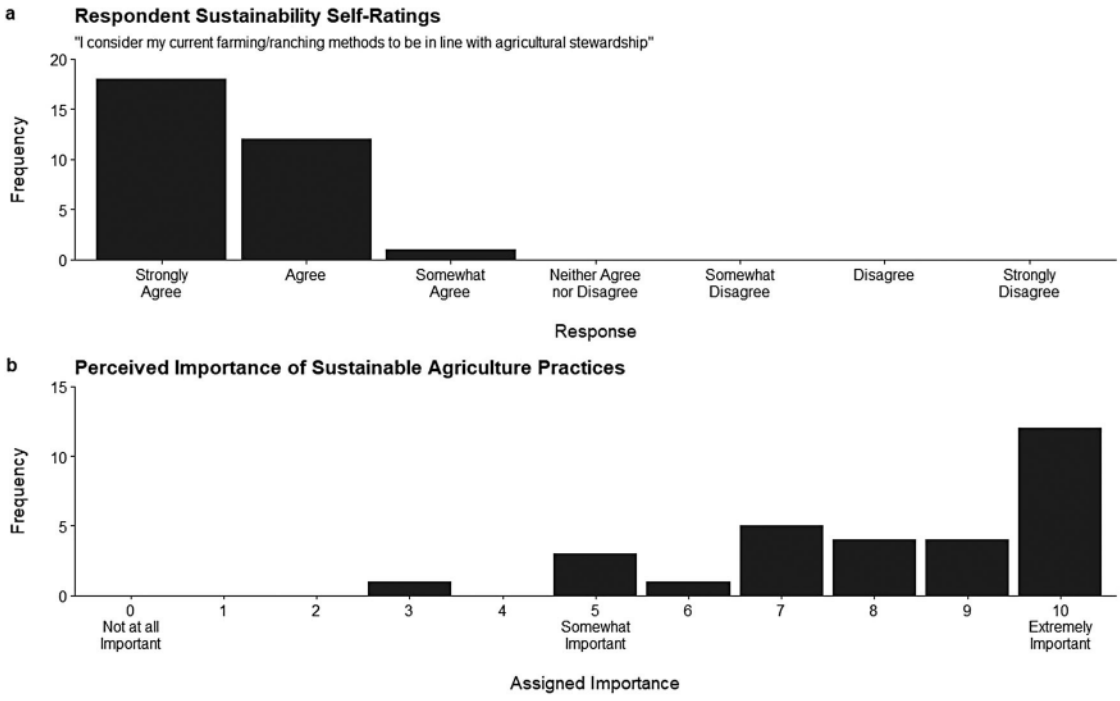

Figure 5. **(a)** Shows the extent to which farmers agreed with the statement 'I consider my current farming/ranching methods to be in line with agricultural stewardship' **(b)** Shows the importance farmers assigned to the sustainable agricultural practices presented in the survey.

assistance, scientific or data assistance, and education were tied for the second most frequent participation form at 47.06%. The average farmer participated in an NRCS programme in 1.48 different ways with a standard deviation of 1.73. In terms of the actual effectiveness of these different types of assistance at increasing the implementation of any given practice, farmers assigned an average value of 6.04, 5.07, and 4.93 to financial, equipment, and scientific assistance forms, respectively, with the maximum of 10 being most effective.

In general, the statistical analyses revealed few relationships between NRCS programme awareness or participation and participant demographics. There was a statistically significant difference based on the sex of the respondent ($df = 1$, $F = 5.235$, $p = 0.0296$) with men participating in more NRCS programmes. The survey sample was not strongly representative of Utah's farmers in terms of sex, however, so this difference is likely not true of the population. The ANOVA analysis also showed that there was a statistically significant difference in the number of ways the respondents participated in NRCS programmes for political affiliation ($df = 5$, $F = 3.443$, $p = 0.0181$). Those identifying as somewhat conservative had a higher mean number of ways they had participated in programmes (mean = 2.33, std = 1.43) when compared with all farmers (mean = 1.61, std = 1.36). Table S4 in the supplementary information summarizes relevant the ANOVA statistics.

4. Discussion

In this study, we analyzed national NRCS programme expenses and acres treated to evaluate the efficacy of these programmes. An explorative questionnaire was then distributed to farmers and ranchers throughout Utah state to assess their attitudes regarding sustainable agriculture practices and NRCS assistance programmes. Examining the national NRCS programme reports over recent decades revealed that there is the potential to increase the efficacy of the programmes as total expenditures have risen both significantly and consistently over recent decades with no correlation to the number of acres treated by these expenditures. The finding that both financial and non-financial assistance are required to fully address the barriers farmers face in implementing sustainable practices confirmed our hypothesis. We also found

that a pattern existed between the importance that producers assigned to sustainable practices and their reasons for doing so. Interestingly, the survey revealed that farmers may have difficulty in self-assessing the sustainability of their operation and that certain sustainable practices would be easier targets for increasing implementation rates than others. Finally, we found that growers reported that the post-implementation impacts of sustainable practices were more-positive than were expected pre-implementation. We now discuss the implications and limitations of these findings for improving the efficacy of NRCS assistance programmes.

4.1. The need to balance financial and non-financial assistance

The survey responses confirmed our hypothesis that non-financial factors, or factors not directly tied to the productivity or profitability of an operation, frequently play an important role in a farmer's decision to implement or not implement a sustainable practice. This is consistent with the conclusions of other researchers which have identified many non-financial hurdles, such as lack of access to equipment, information, markets, or a support network, as major barriers to implementation (Baumgart-Getz et al., 2012; Carolan, 2005; O'Connell et al., 2015; D. A. Weisberger et al., 2021). The wide distribution of implementation factors and obstacles also suggests that efforts to increase implementation rates should seek to address a variety of obstacles rather than one or a few dominant barriers in the implementation decision. This is consistent with the findings of recent meta-analyses that few, if any, variables consistently explain the adoption of sustainable agriculture (Burton, 2014; Knowler & Bradshaw, 2007; Prokopy et al., 2008; Prokopy et al., 2019). In light of this, a more balanced focus on removing financial barriers while also providing scientific and equipment assistance would likely do a better job of removing the wide mix of obstacles that farmers reported (Delaroche, 2020). This conclusion was also reached by a recent review of nearly 18,000 papers on the success of sustainable agriculture incentives programmes which highlighted the importance of technical assistance and extension services in facilitating the adoption of sustainable practices (Piñeiro et al., 2020).

Several reasons could explain why farmers identified financial assistance as the most effective form of assistance despite the wide variety of obstacles they face in implementing sustainable practices. Financial barriers may represent a more 'real' or quantifiable obstacle with a direct connection to the profitability of an operation – a matter which farmers rightfully hold in high regard (Terlau et al., 2019). Another potential explanation is that farmers are limited first by finances and would otherwise acquire the needed expertise (i.e. skills, data, implementation plan, etc.) to overcome the other obstacles. Nonetheless, even with the needed funds, farmers must feel comfortable and confident that they can implement a new practice as efficiently and successfully as possible for them to switch their practices to more sustainable alternatives (Mishra et al., 2018; Reimer et al., 2012). Therefore, while financial incentives to remove the monetary barriers are important, a balanced approach to incentivization and assistance that involves technical assistance and education is required to increase sustainable practice implementation rates as effectively as possible.

4.2. Suggestions for appealing to patterns in producer motives

The pattern in explanations given by survey respondents for assigning either a high or moderate importance to sustainable practices is reminiscent of the previous findings of other researchers. It is well established that a farmer self-identifying as being motivated by stewardship or other non-financial reasons is positively associated with adoption (Gao & Arbuckle, 2021; Liu et al., 2018; Prokopy et al., 2008; Prokopy et al., 2019). For example, recent research has shown that a grower's engagement with sustainable practices is positively shaped by their self-perceived identity as a 'good farmer' or as environmentally-minded (Delaroche, 2020; Dixon et al., 2021; Lavoie & Wardropper, 2021; van Dijk et al., 2016; Zemo & Termansen, 2021). Piñeiro et al. (2020) found in their recent review that one of the strongest motivators for farmers to adopt sustainable practices is perceived benefits for the environment. Public perception and social norms have also been frequently identified as having a positive association with adoption (van Dijk et al., 2016). It has also been shown that more extrinsic motives, such as the impact on profitability, play a strong part in a

farmer's decision to implement a sustainable practice or not as was observed in our moderate importance group (Bopp et al., 2019; Piñeiro et al., 2020). Indeed, it has been shown that sustainable farming initiatives that want to attract farmers who are not autonomously motivated by sustainability (i.e. the moderate importance group), must appeal to motives other than sustainability, such as business opportunities (Triste et al., 2018). Interestingly, several studies have suggested that the environmental stewardship perspective and the profit maximization perspective are competing psychological frameworks that are frequently present in the decision-making process for farmers considering adoption (Floress et al., 2017; Thompson et al., 2015).

While the survey's lack of information on growers who would assign a low, or no, importance to sustainable agriculture is unfortunate, these growers would likely require the most time and resources to increase their implementation of sustainable practices, making it more efficient for NRCS programmes to focus their efforts on the farmers that assign them high or moderate importance. Regardless, future research should attempt to identify the perspectives held by farmers in this low importance group as this group may make up a larger proportion of the population than our sample would suggest.

Successfully appealing to the differences between the high and moderate importance groups will require an approach that ensures individuals are presented with the NRCS information relevant to their motivations. This is consistent with Piñeiro et al.'s (2020) finding that 'policy instruments are more effective if their design considers the characteristics of the target population,' as well as the suggestion of Knowler and Bradshaw (2007) to ensure that 'extension services are geared to the particulars of a locale or, preferably, to individual farmers and their farm operations.' Other recent research has also highlighted that being user-centered is key to the success of digital agriculture extension services (Ortiz-Crespo et al., 2021; Steinke et al., 2021). To this end, we recommend two strategies for communicating with the public and individuals. First, non-specific NRCS communications with the public and growers in general should emphasize both the environmental and economic benefits of sustainable practices. For example, NRCS websites could emphasize both of these areas, thus maximizing the appeal to both the high and moderate importance groups as much as possible. Second, when working with an individual grower, a quick assessment of the importance they already assign to sustainable practices and their reasons for doing so could help to tailor the experience to that specific farmer. For example, as part of an initial conversation with a grower, an NRCS representative or website could familiarize the grower with the list of sustainable practices before asking them, 'On a scale of 1-10, how important do you feel it is to implement the stewardship practices on this list if they are not being implemented?' and then asking, 'Could you explain why you chose that number?' The responses to these two questions could then help the NRCS representative or website tailor the information shared to appeal to that specific farmer. Such interactive online tools have been proven powerful at customizing recommendations to farmers based on individual circumstances and preferences (Peltonen-Sainio et al., 2020).

The lack of a correlation between the farmer's sustainability self-rating and the number of sustainable practices they were implementing suggests that it may be difficult for farmers to accurately assess the sustainability of their operation. Such difficulty in self-assessing environmental sustainability is not unique to producers and presents a significant challenge to increasing implementation (Birdsall, 2014; Mascarenhas et al., 2014). One potential solution is developing a standardized self-evaluation or assessment that could be made available to all farmers, thus providing a way for farmers to see how their operation ranks in terms of their actual and potential sustainability. General Mills currently offers such a tool as part of their planetary responsibility efforts (General Mills, 2019). Another approach is to mimic the strategy used by electric utility companies to reduce energy consumption. In the same way that electric utility bills show how the energy consumption of an individual household compares to its neighbours, thereby motivating the highest consuming households to decrease their energy use (Ayres et al., 2013), a similar approach could be adopted that would allow farmers to see how they compare in terms of sustainability to other producers in the county. This could motivate operations that are underperforming in terms of sustainability to look for new opportunities to improve and be more competitive. In 2018, researchers proposed just such a potential method for measuring the environmental, economic, and social sustainability of agriculture at the county level (Kuo, 2018). Others have proposed similar measurement systems for agricultural

sustainability at various scales, including the farm-level (Zahm et al., 2008; Zinck et al., 2004; Dariush Coteur et al., 2020; Frater & Franks, 2013; Hayati et al., 2010; Nziguheba et al., 2021; Siebrecht & Schmid, 2020).

4.3. Post-implementation experiences exceeded pre-implementation expectations

The finding that farmers reported more positive results post-implementation than were expected pre-implementation could potentially increase motivation among farmers who have not yet implemented sustainable practices to do so as they learn that their peers had a more positive, or at least less negative, experience than might be expected. Prokopy et al. (2019) found that an expected positive yield impact was positively associated with practice adoption and recommended leveraging existing implementation to share the benefits of specific practices or programmes with farmers. This could be especially true of farmers who assigned a moderate importance to sustainable practices considering their focus on the impact of the practices on profitability. It has been shown that negative perceptions of a conservation practice and the perception that its adoption represents a risk are significant barriers to implementation (Ranjan et al., 2019). As a result, sharing the positive post-implementation experiences of farmers with their peers who have yet to adopt sustainable practices could minimize these obstacles. The USDA recently highlighted the importance of tracking and sharing post-implementation assessments to increase the adoption of innovative agricultural practices, citing that farmers are more likely to act on information from trusted sources (Pratt et al., 2021). While many studies have assessed the impacts of sustainable practices on crop yields and other variables (Pittelkow et al., 2015; D. Wang et al., 2021; Weisberger et al., 2019), relatively little research exists regarding grower perspectives post-adoption, meaning that confirming this finding should be a priority for future research (Briske et al., 2017; Brown & Khamphoukeo, 2010). Several alternative explanations exist for why farmers may have reported more positive results post-implementation, such as confirmation bias or the applicability of the practices to different operations, that also merit investigation (Talluri et al., 2018).

The ANN:W ratios of the sorted practices suggest that it would be easier to increase the implementation of some sustainable practices than others. Crop rotation, cover crops, and manure recycling, for example, all had high ANN:W ratios due to their high implementation rates, meaning that a high amount of time and resources would likely need to be expended to get the final, marginal gains in implementation. These resources would likely be better spent on other practices with a lower ANN:W ratio, such as trap crops, which are possibly 'low-hanging fruits'. If, however, an individual producer that was not implementing one or several of these practices with high implementation rates began to engage in NRCS assistance programmes, these practices would potentially make ideal targets for adoption. However, the practices with lower ANN:W ratios as revealed in the study likely represent the best practices to promote on a general, non-individualistic scale. Little literature currently exists that compares how easily implementation rates of different practices can be raised, making it another priority for future research.

4.4. Awareness of NRCS programmes was not a limiting factor

The fact that the average producer in our survey sample was aware of multiple NRCS programmes and had participated in them suggests programme awareness is not an obstacle to participation in assistance programmes. Farmer awareness of, and participation in, programmes was higher in our sample than in most other studies (McCann & Nunez, 2005; McLean-Meyinsse et al., 1994; Obubuafo et al., 2008; Reimer & Prokopy, 2014). Interestingly, the survey responses suggested that farmer awareness of programmes is loosely connected to the programme's reported financial obligations. The CSP, EQIP, and ACEP programmes had the highest percentage of farmer awareness. These three programmes make up three of the four programmes with the highest average financial obligations in Utah state with EWP being the other programme in this group (USDA, 2021b). The fact that EWP is intended to help communities recover from the impacts of natural disasters and is not specific to assisting farmers as are CSP, EQIP, and ACEP may explain why grower awareness of EWP was low despite high financial obligations. Interestingly, CSP, EQIP, and ACEP were not necessarily the programmes that treated the highest number of acres or operations. This suggests that farmers are more aware of programmes that offer

large financial assistance to fewer operations rather than programmes that offer smaller amounts to a larger number of farmers. This conclusion is further supported by the fact that financial assistance was by far the most common form of participation in NRCS programmes by survey participants.

5. Conclusion

This study assessed the effectiveness of NRCS assistance programmes and identified that there is a high potential to improve their efficacy, as revealed by a disconnect between NRCS national spending and acres treated. It then sought to identify ways that these programmes could more effectively motivate and assist farmers in the transition to sustainable agricultural practices by way of an explorative survey. The survey identified several key insights that could potentially help in this effort:

(1) To assist farmers more effectively in the transition to sustainable techniques, financial assistance must be paired more closely with technical assistance to address the wide range of obstacles facing farmers implementing new techniques.
(2) Farmers who viewed sustainable practices as highly important were motivated by public perception and environmental stewardship, while farmers who viewed them as moderately important were primarily concerned with financial factors. By appealing to the differences between these groups of farmers, NRCS information can be presented more effectively to the public and individual farmers.
(3) It is difficult for farmers to accurately assess the sustainability of their own operations. Providing growers with a way to compare their current sustainability with that of their neighbours could improve their self awareness, thereby increasing motivation to implement sustainable techniques.
(4) When reporting practices they had already implemented, farmers saw more positive results than were expected by farmers who had not yet implemented that technique. This pattern could prove to be a powerful tool in helping farmers decide to switch to sustainable techniques.
(5) Certain practices are better targets for increasing implementation than others. Sustainable practices with a high degree of willingness to implement relative to unwillingness or inability to do so, such as trap crops, have the potential to yield dramatic improvements while requiring relatively fewer NRCS resources.

Future research should seek to test these findings and establish whether similar patterns exist in locations other than Utah. As the perspectives of producers are better understood and taken into consideration, sustainable agriculture assistance programmes can be made increasingly efficient. In this way, sustainable practice implementation rates will increase, thus elevating the sustainability of food systems and societies.

Acknowledgments

The authors would like to thank the various organizations that assisted in the distribution of the survey. We also wish to thank Jenny Jo Cox for providing a valuable USDA NRCS perspective during the revision of the manuscript. Finally, we express gratitude to those who reviewed the manuscript and provided suggestions that significantly improved its quality.

Author's contributions

Conceptualization: Carson Thompson; Background research: Carson Thompson, Emilee Severe, Adam J Norris, Jacob Gudmundsen, and Mary Lewis; Survey drafting and distribution: Carson Thompson, Emilee Severe, Adam J Norris, and Jacob Gudmundsen; Manuscript drafting and revision: Carson Thompson, Emilee Severe, Adam J Norris, Jacob Gudmundsen, Mary Lewis, Elisabeth Currit, Nick Newbold, and Benjamin W. Abbott; Supervision: Benjamin W. Abbott.

Availability of data and material

All data and survey materials are archived and available at https://dataverse.harvard.edu/dataverse/byusustainableagsurvey.

Compliance with ethical standards

Because this study involved human subjects, approval was obtained from the Institutional Review Board (IRB) at Brigham Young University prior to commencing (No. E2020-324)

Consent to participate

Informed consent was obtained from all individual participants included in the study.

Consent for publication

Informed consent was obtained from all individual participants to have their responses analyzed and published as part of this study.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding details

This work was supported by the Plant and Wildlife Sciences Department of Brigham Young University using experiential learning funds. Additional funding was provided by the U.S. National Science Foundation award numbers EAR-2011439 and EAR-2012123.

Notes on contributors

Carson Thompson, Emilee Severe, Jacob Gudmundsen, Mary Lewis, Elisabeth Currit, and Nicholas Newbold were undergraduate students in the Environmental Science & Sustainability program at Brigham Young University when this project was initiated. At the time of this publication, Carson Thompson and Emilee Severe have graduated from Brigham Young University and begun doctorate programs at different institutions. Adam Norris is pursuing a masters degree in Environmental Science and Benjamin Abbott is an assistant professor of ecosystem ecology at Brigham Young University.

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