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RESEARCH ARTICLE

A UK survey of the use and management of cover crops

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There is a growing trend in the use of cover crops in the United Kingdom, and whilst research shows there are many soil and environmental benefits, little is known about the farmer's perspective of cover cropping. A survey was designed and distributed to ask farmers about their use and management of cover crops. The online survey received 117 usable responses between January and March 2017, following distribution through social media in the United Kingdom. The survey highlighted that 66% of respondents used cover crops following harvest in 2016. Respondents observed benefits to soil structure, soil erosion control and water infiltration in addition to reductions in the use of chemical fertilisers, herbicide and fuel use. Of those not using cover crops, 90% would consider their use in the future if additional information on their use and benefits were known in a UK context. Changes to the 2016 Basic Payment Scheme guidelines for cover crops would have been welcomed by 71% of respondents using cover crops.

KEYWORDS

cover crops, environment, policy, soils

1 | INTRODUCTION

Cover cropping is gaining momentum in the United Kingdom. Extensive research, largely conducted outside of the United Kingdom has shown that cover crops can benefit: soil structure (Munkholm, Heck, & Deen, 2013; Tonitto, David, & Drinkwater, 2006), soil biology (Reeleder, Miller, Ball Coelho, & Roy, 2006; Roarty, Hackett, & Schmidt, 2017), soil erosion control (Magdoff & van Es, 2000) and nutrient management (Cooper et al., 2017; Wendling et al., 2016). Cover cropping therefore helps to improve soil quality and the wider environment such as water quality and biodiversity (Prechsl et al., 2017).

There is an increasing awareness of sustainably managing soils, with farmers and the UK government recognising the importance of soil to deliver ecosystem services and provide food. The strategy for "Safeguarding our Soils in England" (Department for Environment, Food and Rural Affairs [DEFRA], 2009) proposed the sustainable management of soils by 2030, and elimination of soil degradation. DEFRA continues to support the management of UK soils to balance sustainable, reliable and profitable food production whilst protecting the environment (Agriculture & Horticulture Development Board, 2018; DEFRA, 2018a). Soil faces a number of threats with soil erosion, soil compaction, loss of organic matter and climate change as the principal concerns for soils in England (DEFRA, 2009). Cover crops may be used to address these threats (Maetens, Poesen, & Vanmaercke, 2012; Posthumus, Deeks, Rickson, & Quinton, 2015; Williams & Weil, 2004).

The Common Agricultural Policy (CAP) was reformed in 2013 (Zinngrebe et al., 2017) and from 2015, "Greening Measures" incentivised the use of cover and/or catch crops under Ecological Focus Areas (EFA) in the Basic Payment Scheme (BPS). Guidelines for the use of cover and catch crop species under BPS claims are regulated by the Rural Payments Agency (Rural Payments Agency, 2016) in England. These rules stipulated that cover and catch crops must be a visible mixture of at least two different crops from a prescribed list of eight species, where one species in the mixture must be a cereal and the other a non-cereal species. Additionally, cover and catch crops must remain over a specified period. In 2015/2016, 55,900 ha were planted with cover or catch crops as an EFA feature, representing a 45% increase from the previous season (DEFRA, 2017).

Scientific research supports the use of cover crops to reduce nitrate leaching (Cooper et al., 2017; Macdonald, Poulton, Howe, Goulding, & Powlson, 2005) and to improve soil structure (Chen &

Weil, 2010; Stobart et al., 2015) and weed management (Crotty & Stoate, 2017; Schulz, Marocco, Tabaglio, Macias, & Molinillo, 2013). Earthworms are important soil structural engineers that create biopores for water infiltration and plant root growth, as well as serving an important role in nutrient cycling and availability (Stroud et al., 2016; Yvan et al., 2012). However, the use of cover crops does not always support increased populations of earthworms (Roarty et al., 2017; Stroud et al., 2017). The benefits associated with cover crops may be weather-dependent. The use of soil moisture by a cover crop may be beneficial if rainfall has been plentiful (i.e., removing excess soil water) but can be detrimental if rainfall has been low (removing limited soil water). Nitrogen fixation by leguminous cover crops is also temperature-dependent too (White, Holmes, Morris, & Stobart, 2016).

In the United States, farmers' experience of cover cropping has been identified through an annual cover crop survey initiated in 2012 that now attracts over 2,000 responses. The surveys recorded the trends, management and general metrics of cover crop use in the United States and the effect of cover crops on the yield of the follow-on crop (Conservation Technology Information Center, 2017). However, in the United Kingdom little is known about the farmers' experience of cover crops and if the benefits reported in the scientific literature from controlled laboratory and/or field experiments are materialising on farm. On farm, cover crops need to be practical to implement—but little is known about the management considerations of using cover crops given the lack of relevant research literature for applications in a UK context. EFA "Greening Measures" incentivised the use of cover/catch crops and feedback on the efficacy of cover crop implementation would help to improve the rules in future agricultural legislation. Changes to UK agricultural legislation are imminent given the government's 25 year environment plan (DEFRA, 2018a) and recent consultation paper (DEFRA, 2018b).

This paper aims to present information from farmers about the use and management of cover crops in the United Kingdom using a survey distributed to the UK arable farming community in winter 2017. The survey collected information on the benefits and challenges of using cover crops and the farmer's opinion on cover crop regulations under the "Greening Measures" from BPS 2016 (Rural Payments Agency, 2016). The study aimed to provide insights into the rapidly growing trend in the use of cover crops in the United Kingdom.

2 | MATERIALS AND METHODS

2.1 | Survey implementation and distribution

A UK survey (see Supplementary Information, Appendix S1) aimed at arable and horticultural growers was distributed from January to March 2017. The survey was developed using Qualtrics software (Provo, Utah), (Qualtrics, 2005), an online survey platform. An online survey method was chosen as the farming community has a large and active online presence as well as being inexpensive and easy to administer and manage. Survey links were distributed via twitter, The Farming Forum, emails (to known contacts) and to agronomy companies. No funds were used to advertise the survey. The survey link was tweeted several times from the author's account and accumulated a total of 19,188 impressions, 614 engagements, 80 retweets and 161 tweeters clicked the link; additionally, the Farming Forum post received 581 views. Feedback was obtained from industry professionals at several stages of survey development to ensure the questions were unambiguous and the survey flowed logically for participants. The survey was entitled "Sustainable Soil Management" to avoid biasing results in favour of only cover crop respondents.

2.2 | Survey content

Prior to answering any questions participants were informed about the intention of the survey and how the data would be used and stored. Participants could decline to take part having read this information.

The survey was split into six sections: farm demographic information (Section 1), crop establishment/tillage (Section 2), non-use of cover crops (Section 3), overview of cover crop use (Section 4), cover crop management (Section 5) and soil health (Section 6). The survey contained two pathways; farmers who used cover crops answered Sections 1, 2, 4, 5 and 6, and farmers not using cover crops answered Sections 1, 2, 3 and 6. Survey questions are provided in Appendix S1.

All survey participants were invited to give their name and contact details if they wished to be entered into a prize draw for Groundswell Agriculture event tickets.

Data were anonymised and stored according to data protection guidelines at Cranfield University.

From 226 respondents who started the survey there were 117 usable responses; this represents 0.19% of agricultural holdings classed as cereals, general cropping, horticulture and mixed farms (Armstrong, 2016; Department of Agriculture, Environment and Rural Affairs-Northern Ireland [DAERA-NI], 2017; DEFRA, 2018c; Scottish Government, 2017). Responses were deemed usable if respondents had completed at least Sections 3 and 4 if they were a non-cover crop and cover crop user, respectively. Full responses (all sections completed) accounted for 69/78 and 35/39 for cover crop and non-cover crop users, respectively. Responses were excluded if they did not fulfil the completion criteria outlined above (n = 109). In addition two full responses were discarded because they were from non-arable farms and one response was received from outside the United Kingdom. For many of the UK regions, eight or more responses were received except Wales (0), Northern Ireland (n = 1), Scotland (n = 2) and North West England (n = 2). Collectively, 59,890 ha were farmed by the 117 respondents of which 36,584 ha were planted with combinable crops.

2.3 | Data analysis

Cover crop species-specific data was broadened to genus level groups, for example, fodder radish and oilseed radish were both classified as radish. Soil texture data was also aggregated to heavy, medium and light soils following DEFRA Cross Compliance Guidance (DEFRA, 2006). Heatmaps of cover crop species used on each soil texture class (heavy, medium, light) were produced in the free open source software R. Data from Qualtrics were imported into Excel where summary statistics (percentages) from the answers provided to questions were calculated.

3 | RESULTS

3.1 | Cover crop use

Following harvest 2016, cover crops were used by 66% of survey respondents. On average 21% of the farm area per farm was planted to cover crops. The 39 respondents not using cover crops (following harvest 2016) cited the following top three reasons for lack of adoption (a) they do not fit the current rotation, (b) expense and (c) hard to measure their benefit.

Cover crops were used across all tillage types, although cover crops were more prevalent on reduced tillage farm systems (Table 1). Those practising zero till or strip till were more likely to use cover crops compared to those who power harrow, direct drill and plough.

Over half (56%) the cover crop users had 3 years or less experience of using cover crops. Figure 1 highlights that farmers who have used cover crops for longer are more likely to observe a benefit to soil structure.

Figure 2 shows that farms on heavier soils had a high use of radish and oats in their cover crop. Those on light soils tended to include a clover and phacelia. On average respondents paid £30.30 per hectare for cover crop mixtures and £22.80 per hectare for a single cover crop species. Single species cover crops only accounted for 18% of respondents, whilst 2–3 and 4+ cover crop species mixtures accounted for 51 and 31% of respondents, respectively. Of those who used a mixed species cover crop only 27% used a prepackaged commercially available mixture, 30% had a custom cover crop mixture blended and the remaining 44% of respondents prepared their own mixture. In the first 2 years of growing cover crops, 54% of respondents purchased a prepackaged cover crop, this decreased to 4 and 18% after 3–6 years and 7–10 years+ of cover crop experience.

TABLE 1 Cover crop use related to dominant tillage type present on the farm

Dominant tillage type	Proportion of farms using cover crops per tillage type, % (*n*)
Mixed	100 (2)
Zero till	95 (20)
Strip till	86 (7)
Deep tillage	80 (10)
Shallow tillage	70 (10)
Plough	54 (46)
Direct drill	54 (13)
Subsoil	50 (4)
Power harrow	40 (5)

3.2 | Cover crop effects on soil quality indicators

Over 70% of respondents who used a cover crop reported a benefit from cover crops to soil structure, earthworm numbers and soil erosion control (Figure 3) although soil type was found to be an influencing factor in the latter. No respondents reported a negative effect of cover crops on soil structure, earthworm numbers or soil erosion control. Over 80% of respondents farming light soils reported a benefit to soil erosion control using cover crops compared to 64% on heavy soils. Over 50% of respondents observed positive benefits to organic matter and drainage/infiltration. There was greatest uncertainty of the effects of cover crops on organic matter and nutrient availability, as these returned the greatest

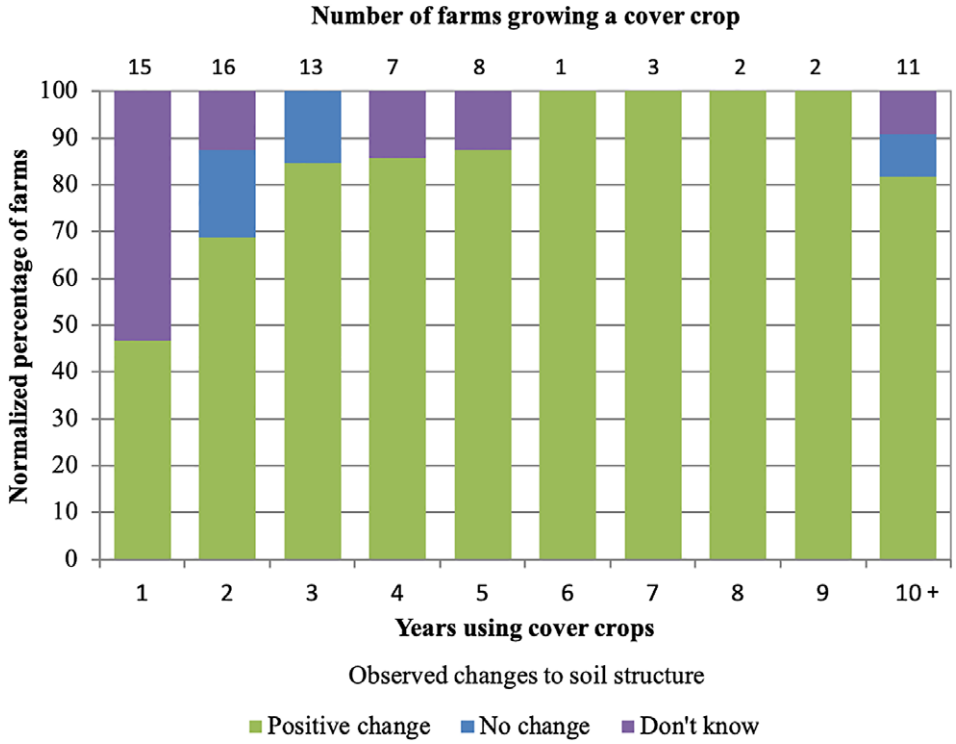

FIGURE 1 Proportion of respondents (*n* = 78) reporting a benefit to soil structure broken down by number of years respondents had been growing a cover crop

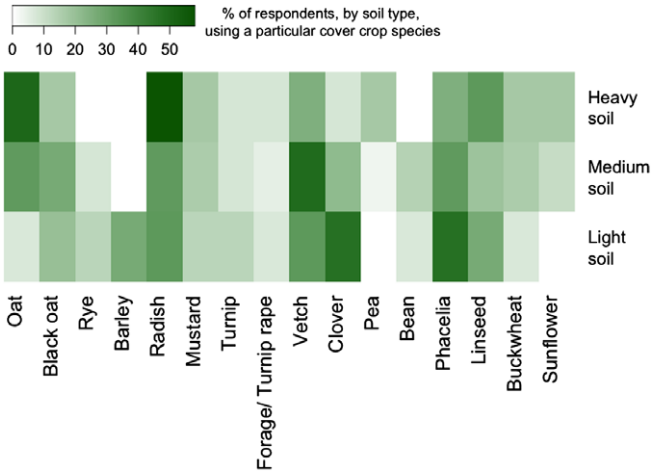

FIGURE 2 A heatmap showing the percentage of respondents who used a particular cover crop species, per soil type

number of "don't know" responses. Also, following cover crops one respondent noted that nutrient availability and the number of working days were negatively affected.

3.3 | Cover crop effect on yield

Yield benefits following a cover crop were reported by 17 respondents in a number of crops (wheat, sugar beet, spring barley and linseed). Nine respondents were able to quantify the benefit. Three respondents reported 0.2, 0.4 and 0.5 t/ha increase in winter wheat yield, with a 0.25 and 0.5 t/ha increase reported in spring wheat and spring barley, respectively. Two respondents reported a 3 and 5 t/ha increase in sugar beet yield. A 50% increase in linseed yield was reported by one respondent. However, two respondents reported yield decreases in spring barley and spring bean crops of 1 t/ha for each crop. No change to yield was reported by 23 respondents and 35 respondents didn't know.

3.4 | Cover crop effects on land management and the environment

Figure 4 highlights that >25% of respondents using cover crops reported a reduction in the use of herbicides and chemical fertilisers as part of their farm management. However, 29% of respondents reported an increase in the use of slug pellets with >33% of respondents noting an increase in slug population, although no change in slug population was observed by 41% of respondents.

3.5 | Cover crop management challenges

Time and labour requirement for the cultivation of cover crops was reported as a challenge (Figure 5) with 17 and 40% of respondents reporting that it was "always" or "sometimes" an issue, respectively. However, 37% of respondents reported that the time and labour requirements associated with cover crops had never been an issue. In addition, 55% of cover crop users reported that cover crop establishment was "sometimes" an issue and 10% of respondents indicated that it was always an issue. Cover crop establishment had "never" been an issue for 19% of respondents and 13% reported that cover crop establishment was "no longer" an issue. Disease concerns following a cover crop had never been a problem for 70% of the respondents using a cover crop, only 12% indicated that disease was sometimes a challenge.

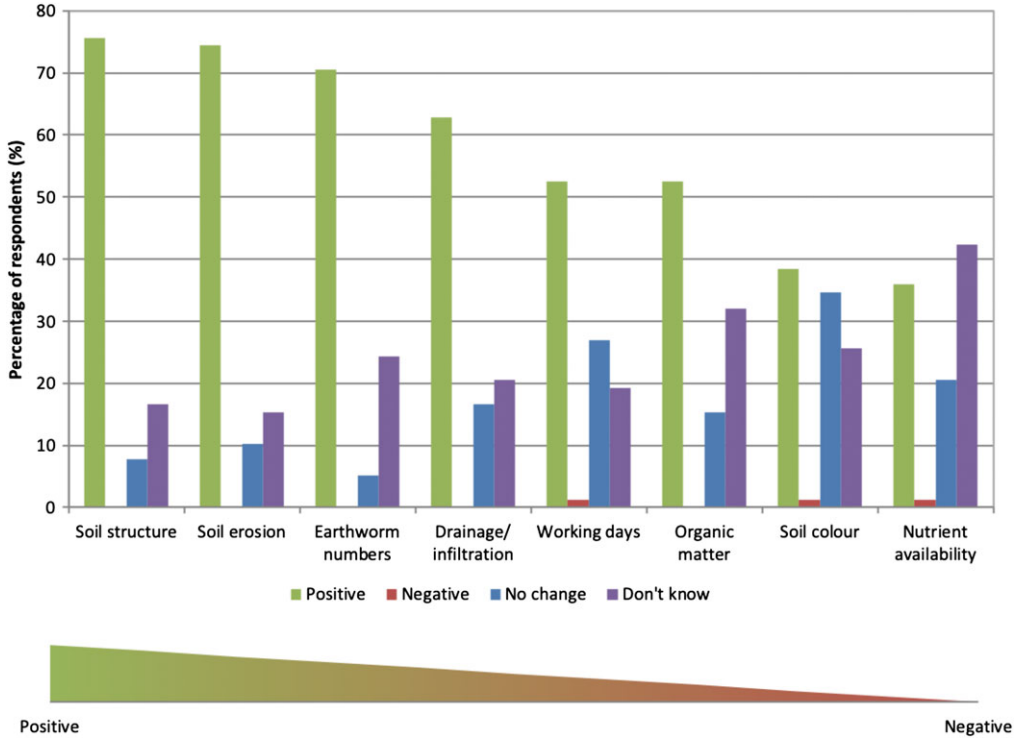

FIGURE 3 Perceived effect of cover crops on soil quality indicators

3.6 | Cover crop termination

Herbicide was the most frequent method used to terminate cover crops (81%), with the majority of the remaining respondents (17%) using some form of cultivation or biomass removal (mowing or grazing). One respondent growing a cover crop mixture of oilseed, fodder and rooting radish relied on natural senescence in order to control the cover crops.

3.7 | Supporting cover crop use

Of the respondents not using cover crops following harvest 2016, 92% would consider their use in the future. The following top three reasons would influence their decision to consider using cover crops in the future: (a) More detailed information on the economics of cover crops, (b) more detailed information on the effect of cover crops and how to measure this on the farm and (c) access to funds/grants to help with seed purchase and establishment costs.

3.8 | Policy supporting cover crop use

Of the respondents who used cover crops, 71% indicated that the EFA guidelines (The Basic Payment Scheme rules for 2016; Rural Payments Agency, 2016) for cover (and catch) crops were not suitable. Many respondents (n = 37) gave recommendations for the improvement of EFA guidelines on the use of cover crops. A selection of the comments are reported below:

"A greater diversity of crops to be included on the list of crops. I have cover crops that are too diverse to qualify as EFA"

"To include other mixes that are more pertinent to our cropping regime, soils and area"

"More species. Being allowed to graze them"

"They are too prescriptive, there is no room for any experiments"

"Include single species cover crops"

A change in the EFA guidelines for cover crop species would influence 20% of the respondents currently not using cover crops to do so in the future.

4 | DISCUSSION

4.1 | Cover crop use in the United Kingdom

A current trend in UK agriculture is the increased use of cover crops. The survey results support this view as 56% of respondents had ≤3 years' experience using cover crops and 75% of respondents have used cover crops for ≤5 years (Figure 1). UK agriculture is relatively new to the use of cover crops compared to the United States and France. Cover crop use in the United States became more prominent following the formation of the Sustainable Agriculture and Research Education (SARE) program in the 1990s (Groff, 2015). A survey conducted in the United States between April and May 2017 reported 88% of respondents (total respondents = 2,102) used cover crops of which only 37% had ≤3 years' experience of using cover crops (Conservation Technology Information Center, 2017). Since 2001, French farmers have been obliged to maintain winter soil cover, and autumn cover crops have been recommended for all nitrate vulnerable zones since 2008 (Justes et al., 2012). There is greater use of cover crops in reduced tillage systems (zero till and strip till) in both the results presented in this article and in the U.S. survey (Conservation Technology Information Center, 2017). Farms practicing zero till are likely to be reliant on cover crop root growth to perform "bio-tillage" of the soil. The biopores created (Stirzaker & White, 1995) are

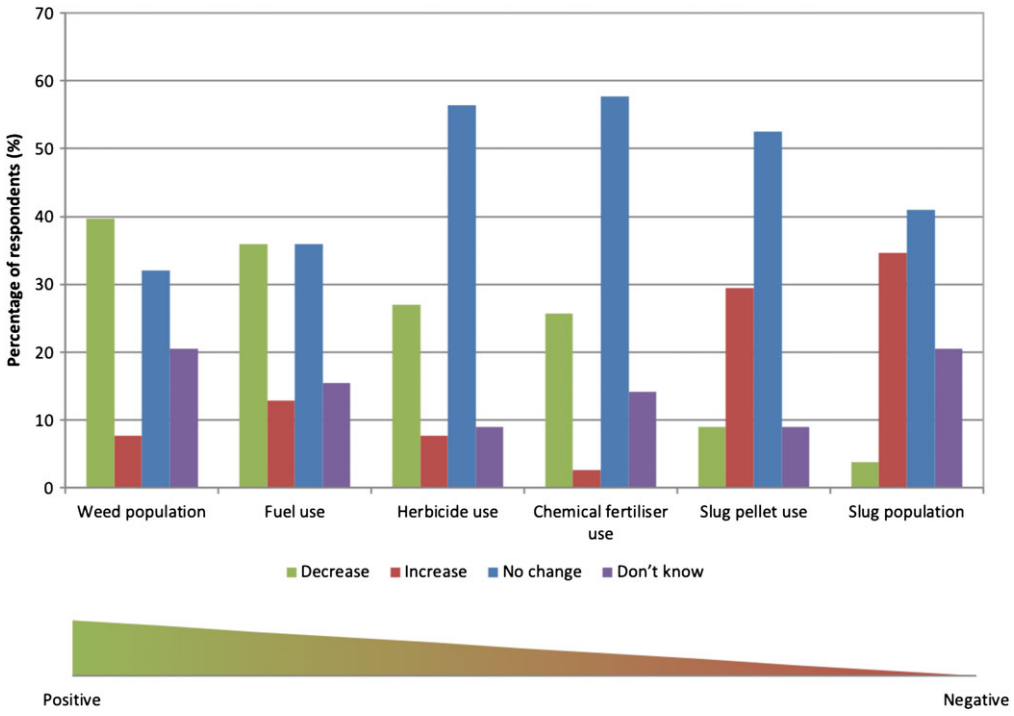

FIGURE 4 Perceived effect of cover crop practices on land and crop management

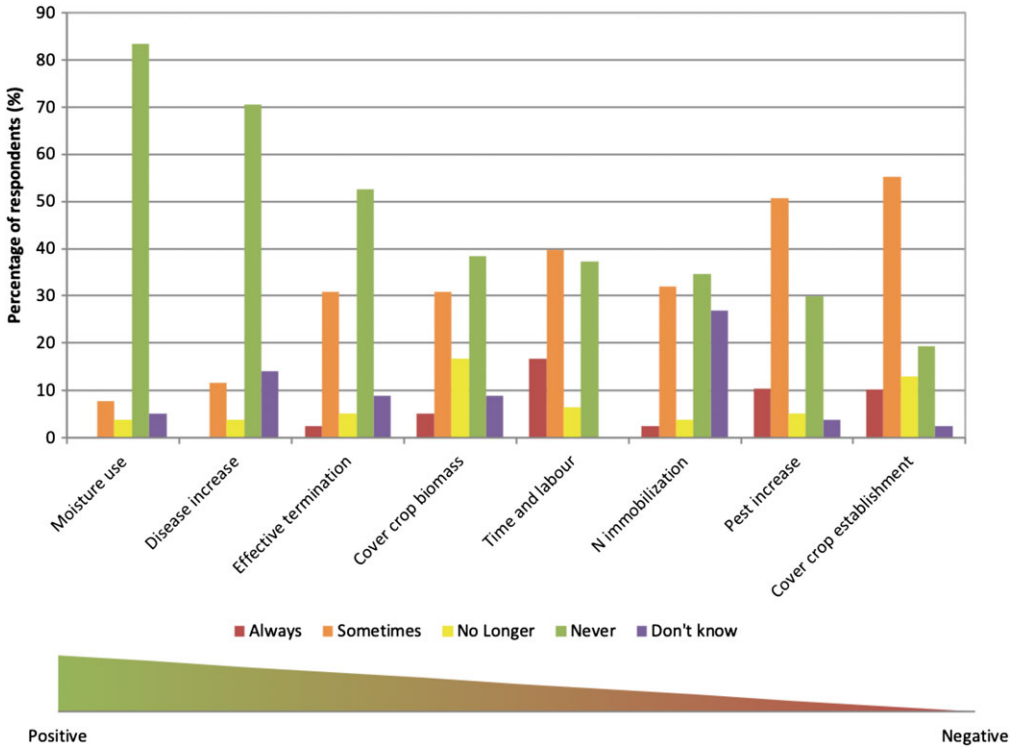

FIGURE 5 Challenges experienced by those using cover crops. Biomass refers to problems that may result from the plant material being too large or having an architecture that interferes with establishing the next cash crop. Moisture use refers to the concern that cover crops may use too much water, creating problems for the establishment of the following crop

preserved by the lack of tillage and aid the following crop's root development (Williams & Weil, 2004).

Of those without previous experience of cover crops, the majority of respondents used prepackaged and commercially available cover crop species. However, after 2 years of cover crop experience there is a sharp decline in the use of prepackaged commercial mixes; instead respondents prepare their own cover crop mix or customise mixes—perhaps as a result of their increased experience and knowledge of what works well for their own circumstances. In the UK survey, the use of cover crop mixtures far out-weighed the use of a single species cover crop. A similar trend was observed in the United States where 65% of farmers planted cover crop mixtures (Conservation Technology Information Center, 2017). Cover crop species mixtures are recommended for multiple ecosystem services (Couëdel, Alletto, Tribouillois, & Justes, 2018), although single cover crop species may be more economical and sufficient for the desired management goals (Finney, White, & Kaye, 2016).

Over 50% of respondents on heavier soils selected a species of radish in the cover crop mix. Research has shown, that radish, with its strong tap root is able to alleviate the effects of compaction (Chen & Weil, 2010), which is a top priority for farmers on heavy soils. Those farming medium-textured soils ranked the improvement of soil biology as a top reason for growing cover crops. The legume, vetch was a common cover crop species choice for respondents farming medium soils, which may help to achieve their aim of improving soil biology. This is because soils after legumes (e.g., peas) have increased earthworm biomass and abundance compared to brassica and some graminaceae species cover crops (Roarty et al., 2017). Additionally, legume cover crops permit greater arbuscular mycorrhizae fungi colonisation of the cash crop (maize, oat, other legume) roots than gramoid or non-legume dicot cover crop groups (Bowles, Jackson, Loeher, & Cavagnaro, 2016). The U.S. survey reported that cover crop species selection has been consistent for several years. Cereal rye, radish, crimson clover and buckwheat were the most popular choices for the cereal grain, brassica, legume and summer annual cover crop groups, respectively (Conservation Technology Information Center, 2017). The widespread use of cereal rye and ryegrass in the United States is not observed in the United Kingdom. The cereal component of cover crops in the United Kingdom is dominated by the use of oat varieties; the reason for this is not clear but could be related to suggestions from seed companies that advise on cover crop species mixtures for farmers that are new to cover cropping.

4.2 | Cover crop effects on soil indicators

Changes to soil properties due to cover crops take time. Jokela, Grabber, Karlen, Balser, and Palmquist (2009) reported that after 4 years of cover crop growth there were no pronounced changes in soil quality indicators (total organic carbon, aggregate stability, pH, phosphorus and bulk density). The survey showed that in the United Kingdom after 1 year of using cover crops <50% farmers observed a benefit to soil structure but this increased to 80% after ≤3 years of cover crop use. The survey highlighted that 92% of respondents (n = 103) answering the soil health section, took a spade "to dig and have a look" at soil structure with 51% of these respondents following a prescribed method such as the visual evaluation of soil structure (Guimares, Ball, & Tormena, 2011). This is similar to farmers in the

United States where 54% observed a benefit to soil health in <2 years and a further 21% observed a benefit to soil health in 2–3 years (Conservation Technology Information Center, 2017). Figure 3 shows that a substantial percentage of respondents using cover crops notice an improvement to soil erosion control, drainage and infiltration and earthworm numbers. Research supports the use of cover crops for soil erosion control (Posthumus et al., 2015) and water infiltration (Folorunso, Rolston, Prichard, & Loui, 1992) although increased earthworm numbers after cover crops is not always reported (Roarty et al., 2017; Stroud et al., 2017).

4.3 | Crop yield

There was a mixed response from respondents regarding knowledge of crop yield following the use of cover crops. The majority of respondents "didn't know" if yield had improved following cover crops. Only two respondents reported yield reductions in spring crops following cover crops; both respondents farmed on heavy soils using a reduced tillage system of direct drill and zero till. The lack of consensus on the effect of cover crops on follow-on crop yield has also been widely reported; reduced yield (Stobart & Morris, 2015), no change to yield (Basche et al., 2016; Gabriel & Quemada, 2011) and increased yield (Bensen et al., 2009; Chen & Weil, 2011). The U.S. Cover Crop Survey (Conservation Technology Information Center, 2017) reported a statistically significant increase in yield of 1.3 and 2.8% for maize and wheat yields, respectively. Even within studies, different cover crop species can be favourable or detrimental to crop yield (DuPont, Ferris, & Van Horn, 2009; Jahanzad et al., 2017; Kramberger et al., 2009). It is evident that cover crops can affect yield positively, negatively or not at all and that this will be related to the cover crop species used, effectiveness of termination and climatic conditions.

4.4 | Effects of cover crops on land management and the environment

Cover crop users observed changes that have potential positive impacts on the environment and ecosystem services, such as: reduced use of herbicide, chemical fertiliser and fuel. Whilst cover crops are not the sole reason for these beneficial outcomes, they are part of broader changes to farm management practice such as reduced or zero tillage. The reduction in herbicide, chemical fertiliser and fuel use, partly through the use of cover crops can help improve air and water quality. Although herbicide is also used for cover crop termination, the reported decrease in herbicide use relates to overall reduction across the farm, potentially as a result of reduced weed burden associated with cover crop use and reduced tillage (Osipitan, Dille, Assefa, & Knezevic, 2018). Leaching of nitrate and phosphate fertilisers are the main pollutants of watercourses (National Audit Office, 2010; Stoate et al., 2001), therefore farm management practices that reduce their use will be beneficial to water quality. Carbon sequestration can be facilitated through the use of cover crops and has been estimated to be sequestered at a rate of 0.32 ± 0.08 Mg of C Ha^{-1} yr^{-1} (Poeplau & Don, 2015).

This UK survey does highlight one management issue of cover crops that can have a negative impact on water quality—the increased use of slug pellets to control slug populations as a result of using cover crops. Metaldehyde present in some slug pellets is often detected in surface water above the EU statutory drinking limit (Castle et al., 2017). However, it should be noted that 53% of respondents report no change in their use of slug pellets whilst using cover crops. Slugs are a major crop pest and if not controlled can reduce wheat and oilseed rape yields by 5 and 4%, respectively (Clarke et al., 2009), costing an estimated £43.5 m per annum in the United Kingdom (Nicholls, 2014). A number of strategies can be utilised to manage slug populations and/or reduce the use of slug pellets when using cover crops. Vernavá et al. (2004) reported that slug populations were greater following vetch or red clover than ryegrass. This suggests that cover crop species is a factor in determining slug populations, thus cover crop species selection could be managed accordingly. Additionally, grass-lined channels (swales) can be used to control the velocity of run-off (DEFRA, 2011), the use of ferric phosphate rather than metaldehyde and payments for not using metaldehyde within high risk catchments may help to reduce the effect of slug pellets on the environment (Castle et al., 2017).

4.5 | Challenges of cover crop use

Cover crop users indicated that time and labour requirement for cover crop operations is a challenge. Often cover crops are established as soon as possible after harvest of the previous crop in order to give sufficient time for growth and biomass accumulation before cover crop termination. However, the establishment of cover crops can compete with time needed for wheat harvest and oilseed rape establishment. Additionally, there will be cover crop termination operations performed in the following winter/spring. Participants of focus groups in the United States also highlighted the time management challenges associated with cover crops but viewed such challenges as management opportunities to adapt practice in a "whole system" approach through trial and error (Roesch-McNally et al., 2018).

The high number of "don't know" responses concerning N-immobilisation by cover crops, highlights an area that requires further research in the United Kingdom to better inform farmers. Research would enable farmers to better manage the termination of their cover crops so that N-immobilisation is better understood for UK soils, climate and cover crop species used. Other notable challenges that could become a focus for the research community in collaboration with the farming community is the pest increase that is reported as "sometimes" an issue for over 50% of the farmers using cover crops (Figure 5) and this is further supported by the issue of slugs in Figure 4.

4.6 | Considerations for future cover crop use

Herbicide (presumably glyphosate but the survey was not specific) was used by 81% of respondents to terminate the cover crop. In December 2017, the European Commission approved the use of glyphosate for further 5 years until 2022 (European Commission, 2018) after much debate due to it being a possible human carcinogen (Tarazona et al., 2017). Furthermore, glyphosate-resistant weeds are reported globally but especially in Australia and the United States

(Heap & Duke, 2017). As it is possible that the chemical may be withdrawn from use in the future, farmers and researchers should focus on the investigation of alternative and effective methods of cover crop destruction. Finding alternative means to terminate a cover crop will add resilience into the management of cover crops and maintain their use and benefit to the wider environment.

The majority of respondents would consider using cover crops in the future (if they do not already) provided there is information and support in terms of (a) more detailed information on the economics of cover crops, (b) more detailed information on the effect of cover crops and how to measure this on farm and (c) access to funds/grants to help with seed purchase or establishment costs. In the United States, similar factors influencing cover crop uptake were reported. Cost share (the contribution of funds per acre for growing cover crops) or incentives were the top influencing factor for farmers to start using cover crops, followed by free technical assistance, more information about cover crop species and local field demo plots with cover crops (Conservation Technology Information Center, 2017). It is surprising that farmers in the United States reported that more knowledge of cover crop benefits and more information about cover crop species would be top influencing factors to take up cover crops given that a farmer-driven research and knowledge-share programme (SARE) has been established for 30 years and has spent many years researching cover crops and other sustainable ideas with farmers (Groff, 2015). Additionally, the United States continues to produce a vast amount of cover crop research compared to the United Kingdom and has a well-established extension network disseminating results.

The effect of cover crops on soil quality and how to measure this may require specialist equipment that is only readily available to scientific research trials; although there are methods available to quickly and easily measure some soil quality indicators. It is going to be vital to educate farmers in appropriate methods to assess soil quality indicators, given that the UK government intends to put "bold new measures to protect and restore soil health" at the heart of a forthcoming agricultural bill (Downing & Coe, 2019). Methods such as the visual evaluation of soil structure (VESS) (Guimares et al., 2011), the visual soil assessment (VSA) (Shepherd, 2003) and earthworm sampling (Open Air Laboratories [OPAL], 2016), are available. Methods such as water infiltration and slaking tests exist and could be carried out on farm. However, these methods will need promotion and demonstration in the United Kingdom similar to methods already demonstrated (VESS, VSA and earthworm sampling) under projects such as "GREAT SOILS" (Agriculture & Horticulture Development Board, 2018) and "Ploughing on regardless" (UK Research and Innovation, 2018). The survey results also highlight that the greatest uncertainty for on-farm measurement is the evaluation of organic matter and nutrient availability; ranked number 1 and 2 by soil health experts as the key indicators of soil health (Soil Security Programme, 2016). These two key indicators of soil health are often measured in the laboratory. However, the development of fast and affordable in field methods for assessing these important soil quality indicators would help ensure that farmers are equipped to measure and monitor their soils as part of the 25 year plan to improve the environment (DEFRA, 2018a).

4.7 | Implications for policy makers

Recently, the Secretary of State for DEFRA, in view of creating a new agriculture policy, announced that public money should be for public goods and ensure a natural capital approach for land use and management. Cover crops can achieve public goods, such as prevention of soil loss due to erosion (Posthumus et al., 2015), reduce nitrate leaching (Cooper et al., 2017), sequester carbon (Poeplau & Don, 2015) and improve biodiversity (Prechsl et al., 2017) as well as form part of a farming system that is less reliant on chemical fertilisers, herbicides and fuel. As UK farmers and researchers develop a greater understanding of the use of cover crops that have benefits on farm but also perform important ecosystem services, will attention turn to how to pay fairly for and subsidise cover crop use? If so, how would a cover crop be judged and what would be the requirements for receiving such financial assistance?

The EFA guidelines (Rural Payments Agency, 2016) for cover crops need to be amended according to 71% of the respondents currently using cover crops. A further 20% of respondents not currently using cover crops indicated that a change in the species of cover crops permitted under EFA would influence their decision to implement cover crops.

Current guidelines require that cover crops must be a mixture, which can add stability and resilience to a cover crop from weather and management decisions (Measures, 2015). However, in some instances a cover crop mixture does not deliver more ecosystem services than a single species cover crop (Finney & Kaye, 2017). A single species cover crop may be easier to manage, especially on organic farms or if it is sown as a companion crop (i.e. with maize) to then become an over winter cover crop. Perhaps whether the cover crop is a single or mixed species should not be the first priority of a policy but rather attaining and maintaining green cover, even if it is a single cover crop species over a certain period of time is more important. A tax credits programme in the United States that supports the use of cover crops (including single species) to reduce water and wind generated erosion requires that 60% land cover must be achieved by autumn and maintained over winter but can then be harvested or grazed in the Spring (Virginia Department of Conservation and Recreation, n.d.). Similar requirements in the United Kingdom would go some way to creating a cover crop policy that is more flexible and helps account for climatic, rotation, geographical and soil type differences between farms. A revision of policy regarding cover crop use would further encourage their use on farms, not only to the benefit of the farmer but also to help deliver ecosystem services to surrounding communities.

4.8 | Limitations of the survey

The survey used 117 responses in total which allowed trends and themes in the use and management of cover crops in the United Kingdom to be identified. This only represents 0.19% of the 63,000 agricultural holdings in the United Kingdom that would fulfil the arable criteria (Armstrong, 2016; DAERA-NI, 2017; DEFRA, 2018c; Scottish Government, 2017). The U.S. survey had a similar response rate of 0.61% that would fulfil the equivalent criteria of agricultural holding

type (United States Department of Agriculture [USDA], 2014). The use of social media and the author's personal account (previously tweeting about cover crops), to distribute the survey may have introduced bias in the uptake and demographics of the farming community that responded to the survey. If the survey was repeated alternative and additional platforms for advertisement and distribution should be considered to appeal to a wider audience. Furthermore, the number of questions should be reduced as this may help to increase the completion rate of the survey.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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