

RESEARCH ARTICLE

The perception and use of cover crops within the island of Ireland

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Abstract

The integration of cover crops within arable rotations is becoming increasingly popular due to their widely acknowledged benefits. Subsidisation of cover cropping is available to eligible farmers in the Republic of Ireland (ROI) but not to Northern Ireland (NI) farmers. There has been little research focus on ROI and NI growers' perceptions about the husbandry associated with cover crops and the benefits of growing them. Surveys to gauge farmer use and perception of cover crops were conducted at two arable conferences, with 55 respondents in NI and 77 in ROI (132 respondents in total). Growers used cover crops mainly to improve and maintain soil structure in an overall bid to enhance soil health in ROI, whereas in NI it was predominantly for forage. The impact of subsidies provided by Ireland and its stipulated policy influences species choice, and farmers were more likely to plant cover crops after later harvested commercial crops, for example, September. Compared to growers in NI, they were found predominantly to plant after crops harvested in August. In ROI, 63% of respondents receiving subsidies would continue to use cover crops if this monetary incentive ceased.

KEYWORDS

cover crops, environment, soil, survey

1 | INTRODUCTION

Cover crops are grown due to their diverse array of benefits ranging from weed, pest and disease suppression (Adhikari, Mohseni-Moghadam, & Missaoui, 2018; Brust, Claupein, & Gerhards, 2014; Dazzo & Garoutte, 2017; Dossey, 2010; Lord, Lazzeri, Atkinson, & Urwin, 2011), water management, including water drainage (Joyce et al., 2002; Zhang, Tan, Zheng, Welacky, & Wang, 2017), as well as water retention (Basche et al., 2016) as a result of better soil structure including soil permeability (Chen & Weil, 2010; Chen, Weil, & Hill, 2014). Cover crops also positively enhance nutrient cycling and reduce leaching (Aronsson et al., 2016; Justes et al., 2012; Teixeira et al., 2016) and can provide over-winter forage for livestock (Kälber, Meier, Kreuzer, & Leiber, 2011; Keogh, McGrath, & Grant, 2012). Attaining these benefits requires farmers to play the vital role of

planting them as part of an arable rotation. Storr, Simmons, and Hannam (2019) conducted a survey to determine a UK farmer perspective on cover crop management practices, including benefits, and found that growers experienced enhanced soil structure, reduced soil erosion and improved infiltration along with reductions in chemical fertiliser usage. However, only one response from Northern Ireland (NI) was captured in this UK-wide survey, warranting the need for another survey to increase knowledge from this specific region and also its immediate neighbour, the Republic of Ireland (ROI).

1.1 | Northern Ireland

In NI, a total of 1,956 farms grow cereals (7.9% of all farms in this region) with an average area of 15.2 ha and only 121 farms had cereal

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areas greater than 50 ha (DAERA, 2020). Grassland in NI accounts for 93% of agricultural land use, with arable representing 5% which equates to 29.7 thousand hectares (Table 1) (DAERA, 2017). Spring barley is the predominant arable crop representing 14.9 thousand hectares, which means a large proportion of total arable land is potentially left fallow over the winter due to associated planting and harvesting dates (DAERA, 2017). Other spring crops such as potatoes, maize, spring wheat and spring oats further add to the area of fallow land, which can be unproductive for about 6 months, depending on season and subsequent commercial crop. Crop rotations that integrate fallow can be beneficial for disease suppression (Ennaifar, Lucas, Meynard, & Makowski, 2005) and increasing soil fertility but this typically means for a full year and is generally practiced in semi-arid regions (Nielsen & Calderón, 2011). However, where fallow land is confined to over-winter in high rainfall climates it can represent a threat to sustainability due to erosion (Boardman, 2013) and nutrient loss (Thapa, Mirsky, & Tully, 2018). In Denmark, regulations mean that cover crops are mandatory to reduce nutrient leaching, specifically, nitrogen (N) and phosphorus (P) loss (Aronsson et al., 2016) and reduce soil erosion and thus protect soil better than bare fallow (Boardman, 2013). Planting cover crops instead of leaving land fallow has the potential to introduce additional productivity, thereby positively intensifying rotations.

The crops grown on the island of Ireland are not diverse, particularly in NI which predominantly relies on cereals as arable crops (Table 1). Cover crops could therefore be a strategy to diversify rotations by integrating species of different plant families to that of the commercial crop which could provide benefits previously highlighted whilst allow farmers to continue to grow the crops they can produce best and have a defined market for (e.g., cereals). Table 1 also shows how less prevalent arable farming is in NI compared to ROI. This could impact upon cover crop use and the reasons for growing them.

1.2 | Ireland

ROI has 10.6 thousand farms (CSO, 2018) which grow cereals, of which only 5,000 specialist tillage (arable) farms grow over 55 ha (CSO, 2012). The arable area in ROI is almost 10-fold greater than that in NI. Spring barley is the predominant crop at 127.4 thousand hectares (Table 1) which leaves a considerable proportion of the arable area fallow over-winter. In ROI, the environmental agricultural land management scheme called the Green Low-carbon, Agri-environment Scheme (GLAS) (running from 2014 to 2020) provides subsidies for eligible Irish farmers to plant catch crops. The GLAS scheme states that the role of these catch crops is to protect soil during fallow periods by reducing soil erosion and surface run-off during heavy rain as a result of increasing water infiltration. Their foliage protects soil from the elements whilst the roots break and condition soil to prevent slumping. The scheme highlights how certain species can increase retention of residual N through reducing leaching. Grazing of these catch crops is permitted from 1 December (DAFM, 2015).

Stipulations of GLAS will impact on farm practice with regard to cover crop use as it specifies the sowing dates, species, retention periods and livestock grazing time-frames (DAFM, 2015). Whilst the arable area in ROI is much greater than that of NI, it is still small in comparison to other sectors of land use. However, arable crops add diversity to the monoculture of grassland, provide high quality straw and grain and offset imported feeds and the nutrients contained in these.

1.3 | Objectives

The survey will help direct future research through identification of current species used, management practices and what growers want to know more about. It is hypothesised that subsidisation schemes

TABLE 1 2018 NI and ROI land use by crop areas (000 ha)

Crop type	NI (ha)	ROI (ha)	NI land use - percentage of total area (%)	ROI land use - percentage of total area (%)
Total grass	807.6	4,157.9	95.4	93.2
Over 5 years	144.5	—	—	—
Under 5 years	663.2	—	—	—
Cereals	29.7	261.6	3.5	5.9
Oats	2	17.8	0.2	0.4
Wheat	6.8	58	0.8	1.3
Barley - Winter	5.8	57.9	0.7	1.3
Barley - Spring	14.9	127.4	1.8	2.9
Potatoes	3.6	8.2	0.4	0.2
Arable crop silage	4.3	3.3	0.5	0.1
Forage maize	1.6	17.8	0.2	0.4
Oilseed rape	—	10.6	—	0.2
Total area	846.8	4,459.4		

Abbreviation: NI, Northern Ireland; ROI, Republic of Ireland.

Source: CSO (2018); DAERA (2018).

affect the objectives and practices of sowing cover crops despite the close proximity in geographical location of NI and ROI. The two regions will show a difference in perception and practices, for example, the why, when and how growers integrate cover crops including the benefits they observe. 'If subsidies were removed, would growers continue to plant them?' is an important question and will indirectly demonstrate if cover crops provide benefits both for crop production and to the environment.

2 | MATERIALS AND METHODS

2.1 | Methods

A survey was designed and conducted on the island of Ireland to identify which species of cover crops farmers were planting, the problems they faced, the benefits that arise from sowing cover crops and the practices used to both establish and destroy them. The term cover crops used in this article includes all crops which are grown over-winter with the aim of improving sustainability of agriculture as opposed to leaving land fallow. It therefore applies to crops sown to provide over-winter fodder, those which are grown to capture residual nutrients (catch crops), those grown to improve soil fertility (green manure) and those to improve soil structure and reduce erosion.

In total, 132 responses were obtained from the two countries involved, 55 from NI and 77 from ROI. The surveys for this study were adapted to the two regions to account for the fact that Irish growers can avail of subsidies to grow cover crops, whilst NI growers cannot. This resulted in some tailored questions to growers from the two countries, whilst sharing common questions on the main theme.

A multiple-choice survey was preferred to other methods of generating information as it allowed in-depth questions to be asked. Survey questionnaires containing 19 over-arching questions (Supporting Information) were distributed at two annual arable conferences for farmers/growers, the Ulster Arable Conference (Cafre, Antrim, Northern Ireland, 2018) and the National Tillage Conference (Teagasc, Ash-town, Ireland, 2018). Events occurred within 3 weeks of each other and were well attended (approximated 250 at the CAFRE/DAERA/UAS/UFU event and circa 450 at Teagasc) by stakeholders from the

arable industry, including growers, agronomists, advisors and students. Five questions (Q5–Q10) were restricted to growers who had previous experiences of planting cover crops. Survey forms were set out on each chair prior to the afternoon session of the event and accessible to all attendees. The NI conference had an update on cover crops for NI, so respondents could have filled out the survey prior, during or after this session. Survey forms were collected after the event to allow respondents ample time and opportunities to complete the survey during those events. The multiple-choice format allowed respondents to select as many options as applicable. They were also given options including 'other – please specify' which allowed additional qualitative information to be gathered. These conferences are the main annual events in each jurisdiction and attract considerable number of growers, agronomists, advisors and students. These are all key stakeholders in the industry which are important to engage with. Furthermore, if future research is conducted the results can be disseminated at these conferences, being an efficient way communicate the results back to as many as possible to facilitate integration into the industry.

2.2 | Summary of results and graphs

Results from the survey were summarised as response numbers and percentages. Graphs were created using Graphpad Prism version 7.00 for Windows (Graphpad Software, La Jolla, CA; www.graphpad.com).

3 | RESULTS

3.1 | Respondent occupations, understanding of cover crops and prevalence of using them

The 132 responses to this survey are similar to the number of responses in the surveys by Storr et al. (2019) and Jones (2016), 117 and 168, respectively. In this survey, growers represented 64% and 68% of total respondents sampled in NI and ROI, respectively. As respondents were able to choose multiple occupations (Supporting Information), there were higher totals in Figure 1 than the actual

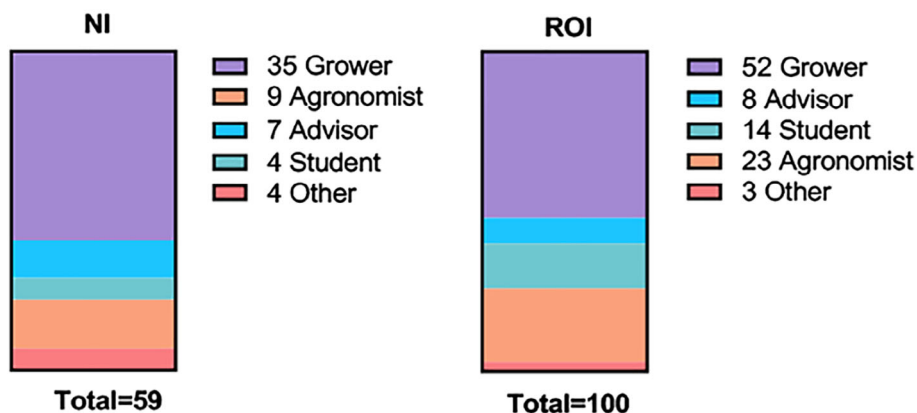


FIGURE 1 Occupation of respondents by country

number of respondents, for example, they can be both an advisor and grower.

In both regions, Figure 2 shows the respondents' perception of the function of cover crops. The main function identified was for improving soil structure in both regions. The roots of a growing cover crop can loosen soil, decrease bulk density and penetration resistance and thus enhance soil structure (Chen et al., 2014) and reduce soil erosion (Kaspar, 2009). Meehan and Frost (2013) found in a survey that 63% of growers in NI indicated that compaction problems were present on their land, primarily because of wet seasons and modern heavy machinery, explaining the predominant function selected in this current survey. No such study was conducted in ROI for comparison. Cover crops could play a vital role in relieving the high compaction risks associated with high rainfall climates through increased evapotranspiration compared to fallow. However, little research has been conducted on evapotranspiration of cover crops (Jones, Kurnick, Miller, Olson-Rutz, & Zabinski, 2015). The findings by Storr et al. (2019) showed that 70% of survey respondents who used cover crops experienced a positive effect on soil structure and soil erosion following commitment to using cover crops over a number of years. This was identified as the predominant positive effect.

The secondary reasons identified for growing cover crops were to improve soil fertility and to capture residual nutrients that are leachable. This demonstrates that respondents are aware of the detrimental impacts that nutrient loss from land has on the environment. However, their awareness may also be due to the fact that they understand that this is an economic loss. No respondents indicated that cover crops have no benefits which is encouraging and an important finding.

Of those respondents who identified as growers, 82% and 92% considered planting a cover crop in NI and ROI, respectively. In NI, 54% of growers have previously planted cover crops compared to a higher proportion of 77% in ROI which demonstrates the higher prevalence of and increased willingness to integrate cover crops in ROI. The larger proportion of ROI growers who plant cover crops not only reflects both the influence of a greater area and prominence of tillage as land use in ROI (Table 1) but most likely also the effect of subsidies. In 2017, an estimated 20,000 ha in ROI were sown with cover crops and, in that

year, subsidies equalled 155 Euros/ha (Minnock, 2017). The effect of subsidies results in a profitable crop when seed costs and, drilling costs are deducted. In perspective, the land area sown to cover crops in ROI is two-thirds of the NI arable area (Table 1) (Minnock, 2017).

3.2 | Why do you (did you) grow cover crops? (open to only those respondents who have experience of growing cover crops)

Responses from those who have previously grown cover crops before indicated that in ROI the main reasons for planting them was to improve soil health, soil structure, capture residual nutrients and increase organic matter content. In NI, they were grown to provide forage for livestock, improve soil health and structure and capture residual nutrients to prevent leaching (Figure 3). The main

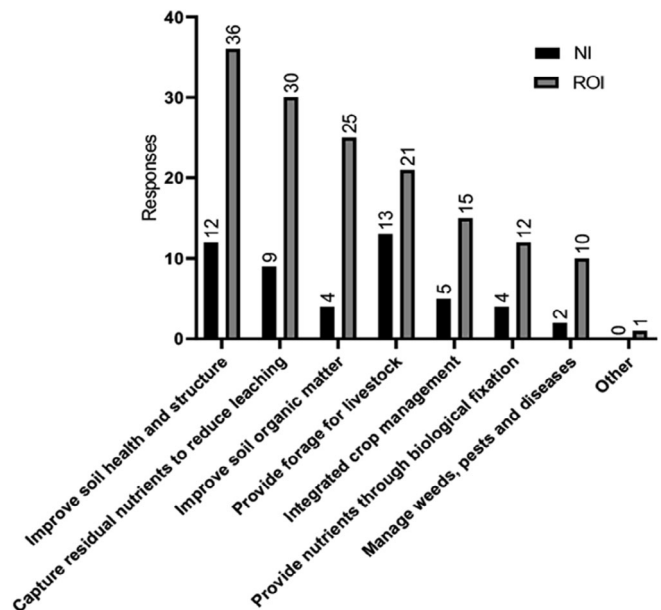


FIGURE 3 Why do you grow cover crops?

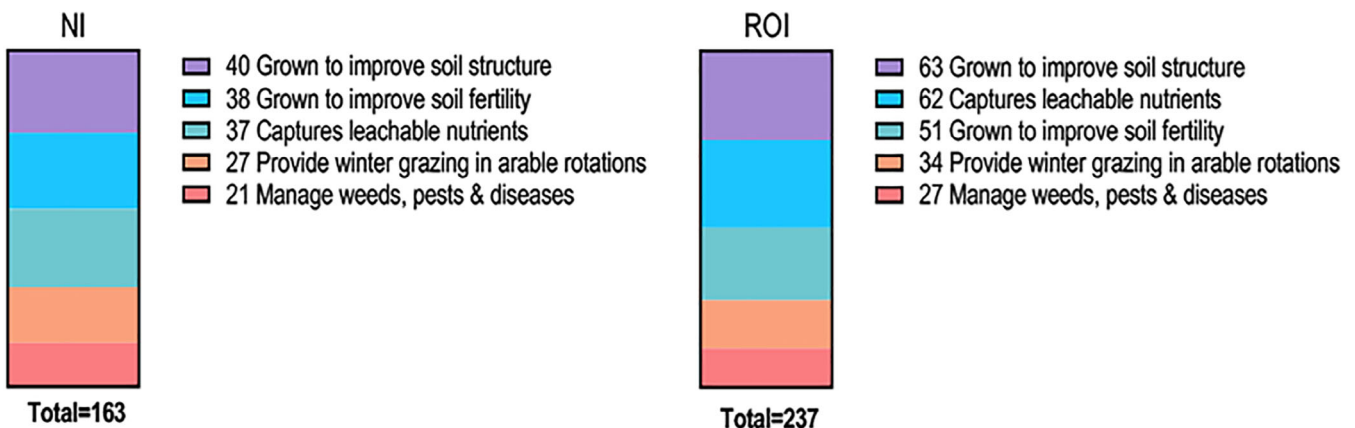


FIGURE 2 What are the functions and benefits of cover crops?

reason to sow cover crops in NI, that is, to provide fodder, is due to its intensive livestock sector (NISRA, 2020), showing that NI has different objectives to ROI. The 'other' option was selected by a respondent in ROI which may have been due to there being no category for 'due to subsidies' and selected this category for this reason.

Growers have a clear appreciation of the need to reduce leaching/loss of nutrients (Figure 3), echoing the response to the 'perceived benefits of cover crops' question asked at the very start of the survey from all respondents. To provide nutrients through biological fixation was of low priority. Only 8% of growers in NI planted cover crops to improve soil organic matter compared to ROI, where 24% of growers identify this as a reason. This may be due to a higher proportion of grassland in NI arable rotations (DAERA, 2017). Grass is highly effective in maintaining soil organic matter (Christensen, Rasmussen, Eriksen, & Hansen, 2009). Furthermore, the intensive livestock sector provides better access to organic manures. In NI, 94% of respondents use manures compared to 78% in ROI. The application of organic manure to land is a highly effective way to return and maintain soil organic matter, especially when integrated with cover crops (Sapkota, Askegaard, Lægdsmand, & Olesen, 2012). Planting to manage weeds, pests and diseases was of low importance in both NI and ROI, perhaps as growers still have access to a large armoury of agro-chemicals to maintain crop quality and productivity.

In addition, on the island of Ireland, the high number of mixed farms growing low areas of arable crops (CSO, 2012; DAERA, 2020) could mean there is a good rotation with grassland which is a highly efficient tool to manage weeds and reduce reliance on pesticides (Cook et al., 2010). Weed suppression could be happening due to species such as the brassicas, which are the predominant cover crops grown in cropping rotations and are highly effective in general for weed suppression (Brust et al., 2014).

3.3 | Species used

The most common species used by those who have grown cover crops in NI was stubble turnips, followed by fodder rape, tillage radish

and mustard – all brassicas. A greater diversity of species was grown in ROI, the most common being fodder rape followed by vetch, stubble turnips and forage radish (Figure 4). In the 'other' category of the ROI survey, oats appeared in nine of the 15 responses. Additional species that appeared in this category included, sunflower, linseed, forage maize and sainfoin. In NI, the only two responses to 'other' were oats and kale.

The predominant species grown in NI are brassicas such as stubble turnips and forage rape which ties in with the fact that cover crops are primarily grown to provide forage. Brassicas are high yielding and high in protein making them effective grazing crops (Keogh et al., 2012) (Figure 4). The large ruminant livestock industry in NI (NISRA, 2020) means that cover crops have the potential to reduce over-winter feed costs of conserved forage and concentrates. The second most frequently used species was fodder rape which is also of high forage value (Keogh et al., 2012). The main species in NI are all brassicas which have been found to be the most effective in reducing leaching of both N and sulphur (S) (Aronsson et al., 2016; Couëdel, Alletto, & Justes, 2018; Couëdel, Alletto, Tribouillois, & Justes, 2018). Storr et al. (2019) investigated species used and divided respondents by soil type (heavy, medium or light) and found that brassica species were more commonly sown in heavy soils compared to light soils, whereas legumes were more widely sown on medium and light soils. The reliance on brassicas in NI could also be due to the large proportion of heavy land there, to which they are naturally better suited.

In ROI, a more diverse range of cover crops is used, this mirrors the list of species specified by the GLAS scheme regulations including buckwheat, crimson clover, berseem clover, forage rape, mustard, oats, phacelia, rye, tillage radish, vetch, leafy turnip, peas and beans (DAFM, 2015). Alternative options also included less commonly used species such as sainfoin, sunflowers, linseed and forage maize. Respondents were asked whether the cover crops were grown as a mixture or in monoculture. ROI had a larger percentage grown as mixtures (73%) compared to 60% in NI. In ROI, a more varied range of species is used which is probably due to GLAS stipulations which include the mandatory sowing of a mixture of species from a specified

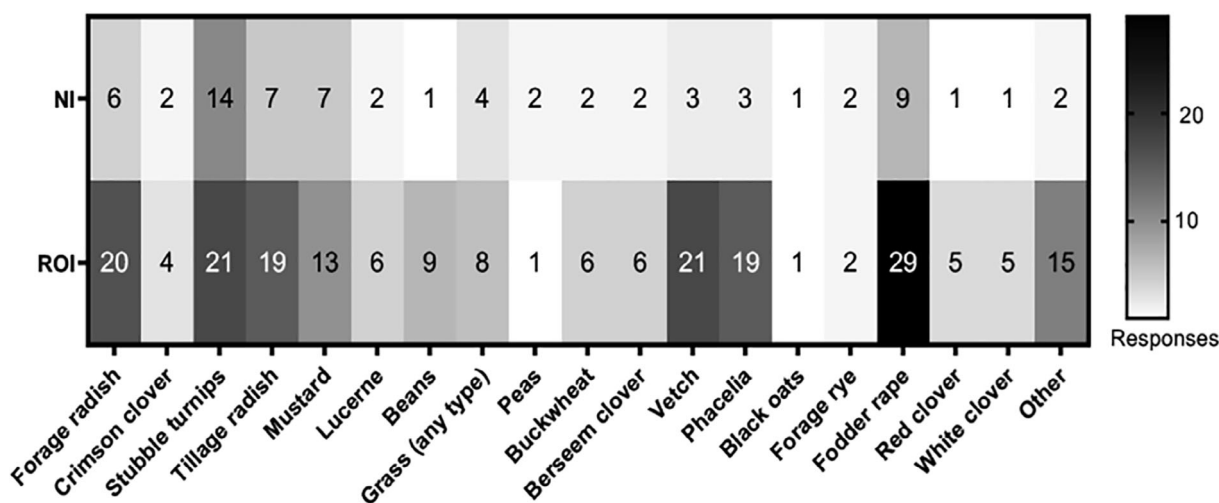


FIGURE 4 Heatmap of species used by country

list in order to avail of the subsidies. This explains why using a mixture is more prevalent in ROI compared to NI. The main species used in NI have low seed rates and low-cost seed and can therefore be a relatively inexpensive option in comparison to other species from the more diverse range used in ROI. When respondents were asked about the price they were willing to pay for seed, there was little difference between regions, with the majority indicating the £10–15/acre range. This could mean that the more varied range of species used in ROI is achieved through low seed rates of more expensive species.

3.4 | How did you establish them?

Of those who had previously grown cover crops, scratch and drill was the most widely used establishment method in NI and scratch and broadcast in ROI. Ploughing in NI accounted for 15% of establishment compared to only 5% in ROI, whilst direct drilling accounted for 22% in ROI compared to 15% in NI (Figure 5). A lack of machinery to facilitate cover cropping is not a barrier to adoption: Cover crops favour methods of reduced tillage, for example, scratch and broadcast to maintain least cost rather than using a plough which cultivates to a greater depth and is thus more costly. The plough is the predominant tillage tool in NI accounting for 92% (DAERA, 2016) of crop establishment and hence it was thought that this would have had a greater prevalence of use for establishing cover crops.

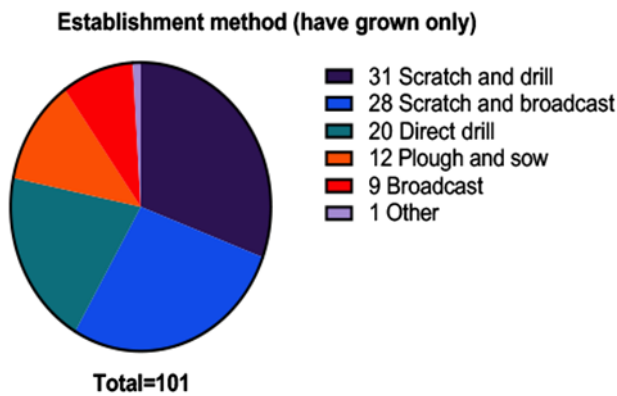


FIGURE 5 Responses to establishment method (NI + ROI). NI, Northern Ireland, ROI, Republic of Ireland

3.5 | If you have grown a cover crop, what benefits (if any) did you see in the subsequent crop?

Growers who previously planted cover crops reported mixed responses for benefits observed in the subsequent commercial crop produced (Figure 6). Benefits included: increased yield, reduction in fertiliser input requirement and a healthier crop. A majority, 56 of the 97 responses, reported that they found benefits, whilst 40 indicated that they saw no difference. The ‘No difference’ response was split in two: ‘no difference and not worth it’ and ‘no difference but an investment in soil health’. Only two growers in NI identified ‘no difference and not worth it’. There were no such responses in ROI where 20% of all the respondents acknowledged increased yield and a healthier commercial crop following the cover crops; 17% also recorded a reduction in required fertiliser input. These are the benefits required to make the practice of cover cropping profitable and maximise integration into arable rotations, particularly where no subsidies are provided. Whilst the majority of ROI growers observed no benefit in the subsequent crop, they did indicate that it was an investment in soil health and therefore worthwhile. This is positive, as cover crops are a mechanism towards more sustainable production (García-González, Hontoria, Gabriel, Alonso-Ayuso, & Quemada, 2018). The survey by Storr et al. (2019) found a greater proportion of growers observed greater benefits in soil structure with increased number of years integrating cover crops. This demonstrates that cover crops require commitment. Growers realise that cover crops are an investment and understand that the benefits of integrating cover crops are small. However, whilst the benefits are hard to measure/observe, they accumulate with time into tangible positive effects which is what these growers are investing in, that is, a system that has a greater benefit on soil health to avail of longer-term benefits which was the predominant reason for planting in ROI (Figure 3).

3.6 | What problems do you have on your arable land that cover crops could contribute to resolving, improving/mitigating? (open to all respondents)

Soil structure concerns ranked as the greatest problem on arable land in both NI and ROI with 28 and 47 respondents, respectively,

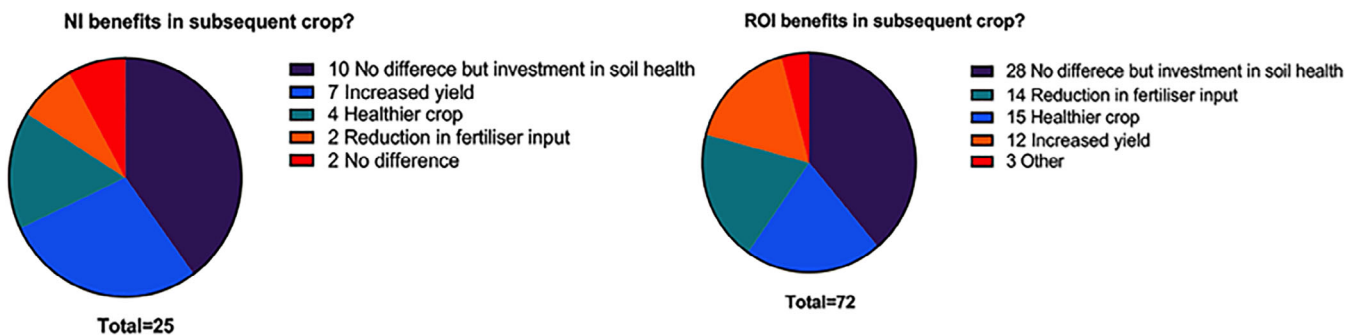


FIGURE 6 Benefits observed in subsequent crops?

selecting this (Figure 7). The other three main concerns are soil health, compaction and loss of nutrients. Soil structure is arguably different to compaction as it encompasses the functionality of soil which includes porosity, the mix of air, water and soil, whereas compaction is a direct problem due to increase in bulk density. The problems identified are all intrinsically interlinked with soil structure and soil health. Poor soil health and structure will increase susceptibility to

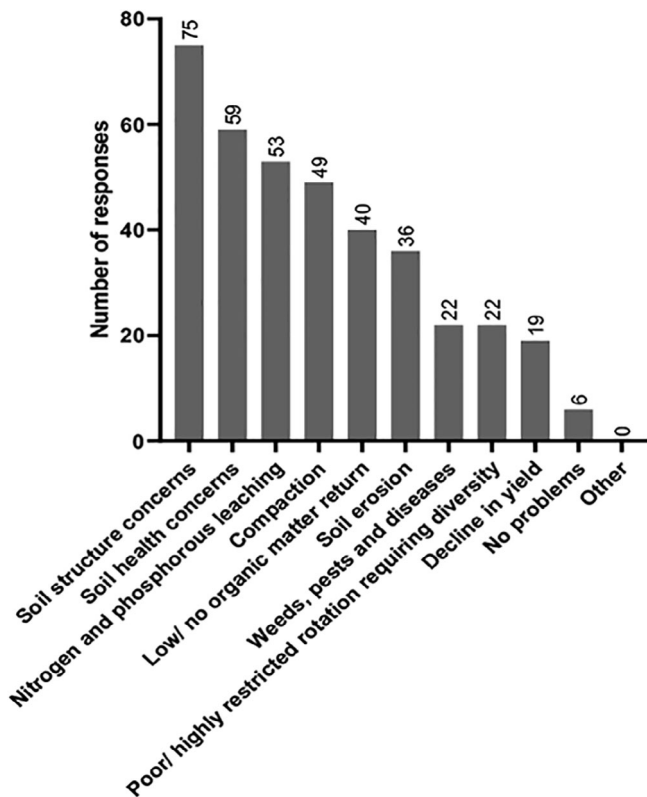


FIGURE 7 Problems on your farm?

compaction and thus nutrient loss (Nawaz, Bourrié, & Trolard, 2013; Shah et al., 2017).

Weeds, pests and diseases were considered to be of low importance, possibly due to the prevalence of agro-chemicals currently available for control. Growing pressure to revoke the licence of the most common herbicide, glyphosate, combined with an increasing list of countries banning its use, could lead to year-on-year increments in growers planting cover crops to manage weeds. Only 36 people highlighted soil erosion as a problem on their farm. This is relatively low, despite the European Commission estimating that soil erosion affects 7.2% of the total agricultural land in Europe and is estimated to cost European farmers 1.25 billion euros annually where conventional plough-based production cropping increases the risk of soil erosion (EC, 2018). Mitigation methods include minimum tillage and maximising ground cover through plants/residue to act as a physical barrier reducing the force of the rain on the soil and where the plant roots act as an anchor. Cover crops provide an effective mechanism to increase soil cover and roots in comparison to fallow (FAO, 2020; Gómez, Sobrinho, Giráldez, & Fereres, 2009). Only six people indicated that they had no problems on their arable land, showing either a lack of interest and perception or that they are efficient farmers.

3.7 | Use of organic manures and application rates

Amongst all the NI growers, 94% (52 out of 55) used organic manures or slurries on their arable land/crops, compared to 78% (60 out of 77) in ROI. This demonstrates the importance of slurry in the NI arable sector as a method of replacing/supplying nutrients at lower costs combined with the necessity of livestock enterprises requiring sufficient land for nitrate loading due to local policy (The Nutrient Action Programme Regulations 2019–2022). The predominant manure used was cattle slurry, in both NI and ROI (Figure 8). The prevalence of

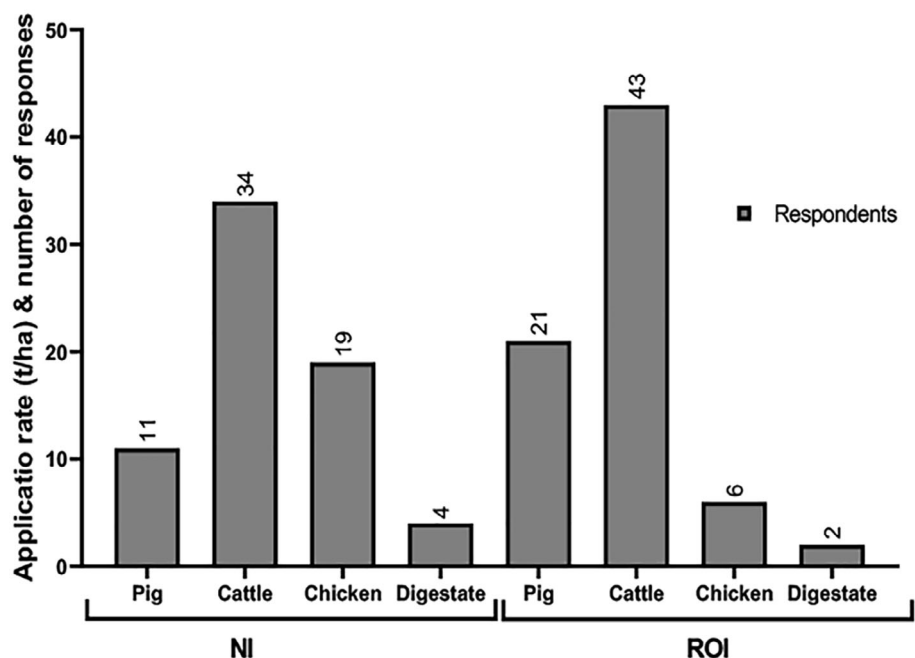


FIGURE 8 Manure used by respondents in each region

arable farmers using organic manures may suggest why growing cover crops to biologically fix nitrogen ranked very low and why to capture residual nutrients ranked so high. The importance of slurries as sources of nutrients in arable production could mean that incentivising the practice of sowing cover crops over-winter followed by spring commercial crops as an alternative to sowing commercial winter crops could produce a beneficial mechanism to increase N and P efficiency through their reduced loss by the cover crop and an increase in nutrient efficiency where slurry is spring applied. Moreover, utilising slurry on arable crops reduces dependence on chemical fertiliser input (AHDB, 2017). Slurry applied post cover crop would reduce the fertiliser dependence and could help address the fact that spring crops typically have lower gross margins than winter crops (DAERA, 2017, 2020). This could increase the profitability of the spring crops, through reduced inputs whereby increased yield would

also improve output. Of all respondents, 16 growers indicated reduction in fertiliser requirements whilst 19 growers highlighted an increased yield due to the cover crop (Figure 6).

3.8 | What crops do you grow and between which rotations would you grow over-winter cover crops?

Spring barley was the most cultivated crop in NI and ROI, followed by winter barley, then winter wheat (Figure 9). In ROI, a greater proportion of growers planted winter barley than winter wheat whereas in NI, the same proportion grew winter wheat as winter barley. Winter barley's early harvest allows for an ideal entry to cover crops. This was observed when respondents were asked where in a rotation they would consider sowing cover crops (Figure 10). The most common

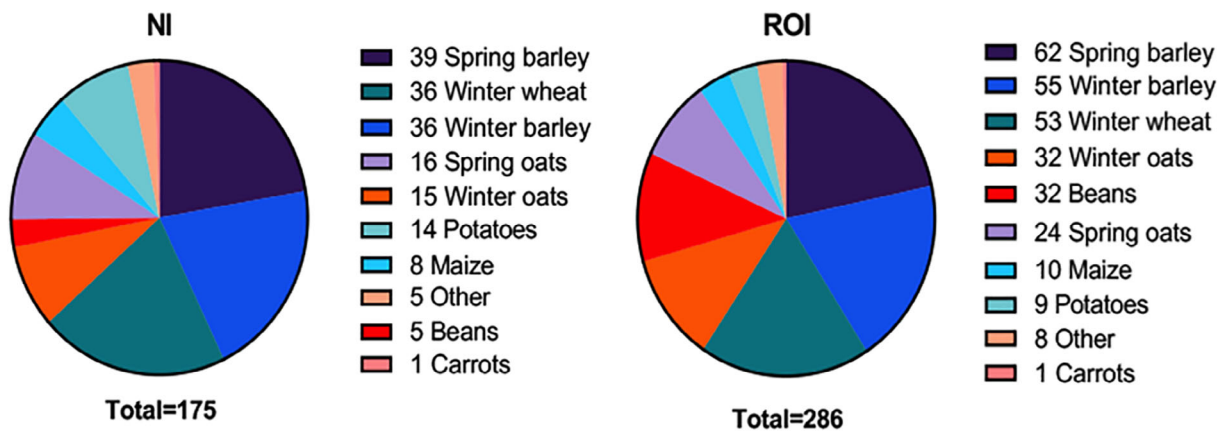


FIGURE 9 What crops do you grow?

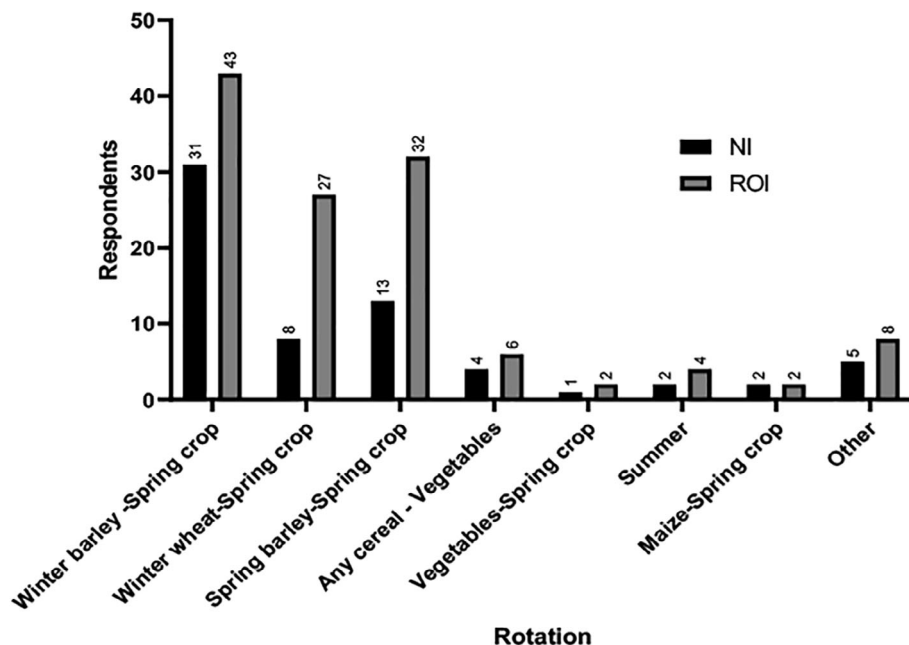


FIGURE 10 Between which crops would you consider growing a cover crop?

response from growers in both NI and ROI was between winter barley and a spring crop. Sowing cover crops after winter barley provides greater flexibility and more conducive growing conditions than sowing cover crops after winter wheat or spring barley which have later harvests. More respondents in ROI considered planting cover crops after wheat or spring barley than in NI.

A 75% and 56% reduction in forage rape and stubble turnip dry matter yield, respectively, was found in ROI when sowing was delayed from 1 August to 31 August (Keogh et al., 2012). This dry matter reduction decreases grazing potential and increases relative costs of the cover crop as a feed, which leads to a decline in monetary gain from sowing (where no incentive is provided). This, combined with deteriorating growing conditions, could be the reason NI growers are less likely to plant after winter wheat or spring barley. These crops are typically harvested from September onwards, thus creating a less profitable situation at later sowing dates. This results to less land being sown in cover crops and more being left fallow, which does not protect the soil or waterways. Therefore, incentives which encourage planting later need to be identified in a bid to reduce the amount of land left fallow over winter. Whilst sowing cover crops as early as possible gives optimal biomass production, the fact that the GLAS scheme subsidises growers to sow as late as 15 September encourages the planting of cover crops after commercial crops that have later harvests than winter barley. This maximises the environmental and economic benefits associated with sowing more land to cover crops, thereby increasing overall benefits.

The second most common rotational option for cover crops in both NI and ROI was following spring barley prior to a spring crop. As continuous spring barley is the most common crop, a large proportion of land is left fallow over winter which could alternatively be planted with cover crops. Therefore, there is a need to identify species that will grow adequately in this rotational position, exhibiting high vigour at the later sowing dates post-harvest of spring barley or winter wheat. This would provide a strategy to help support and encourage later drilling.

3.9 | Sowing technique and method of destruction

In ROI, a much lower proportion of respondents plan to use a plough to establish cover crops. Ploughing and sowing is the most intensive tillage technique and only accounted for 10% of all responses for both NI and ROI (Figure 11). This shows a clear leaning towards a less intensive sowing technique. Destruction technique was variable with the 'other' section including grazing as a prevalent option, especially in NI. Killing the cover crops with herbicide followed by ploughing are the most common practices used to achieve destruction and incorporation in both NI and ROI (Figure 11).

3.10 | Do you receive subsidies for growing cover crops? and if subsidies were removed, would you still grow cover crops? (ROI only)

In ROI, 49% of growers answered that they were receiving subsidies (Figure 12). Of the 'yes' replies, 63% indicated that they would continue to grow cover crops if subsidies were removed. This indicates that these growers had a positive experience of growing cover crops and that the practice is viewed as viable without subsidies. This survey suggests that when subsidies are available, growers may change their reasons for growing from the provision of forage (in NI) to being more focused on soil health (in ROI). Most importantly, subsidies mean farmers are more likely to sow later. This could optimise the total area sown to cover crops and maximises their environmental benefit.

3.11 | Growing cover crops is much more widely adopted in mainland Great Britain compared to NI. What are the biggest limitations we have? (NI only)

Respondents were asked why cover crops are a less common practice than in Great Britain and what the perceived limitations are in NI (Figure 13). Climatic factors of a shorter growing season to establish a

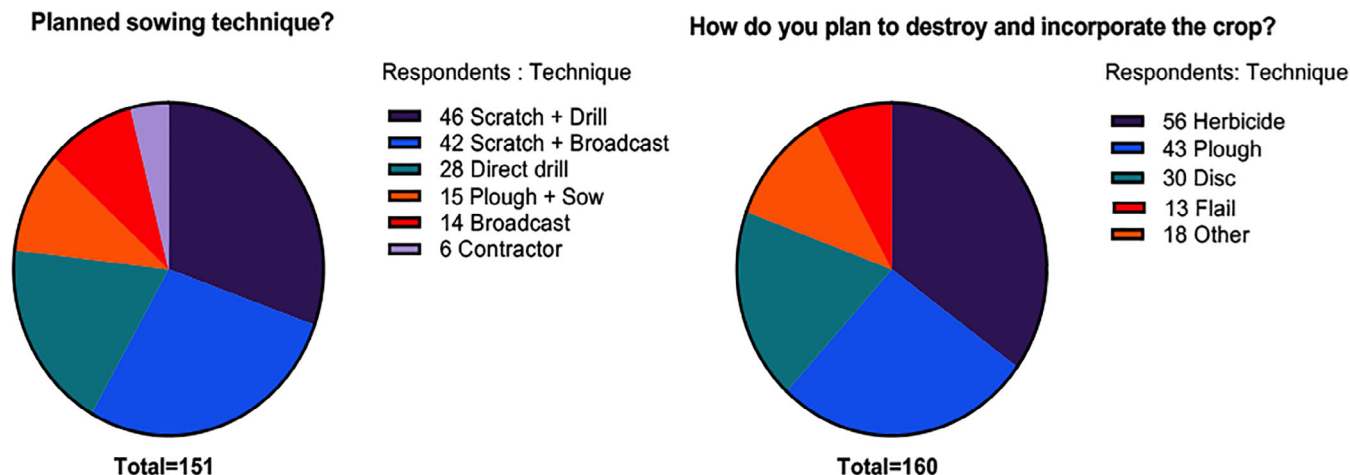


FIGURE 11 Planned sowing techniques and method of destruction (NI + ROI responses). NI, Northern Ireland, ROI, Republic of Ireland

successful cover crop and higher autumn rainfall were the most common responses. In NI, a predominately grassland-based agricultural system facilitates a rotation with grass which is highly effective in raising organic matter of soils (Carolan & Fornara, 2016) and as a break crop. However, only 8% thought that this was a reason why cover crops are not required in NI compared to mainland great Britain (GB), which shows growers understand other benefits of cover crops, for example, enhance soil structure, retain nutrients and improve soil fertility. Cover crops can allow increased transpiration compared to a rotation of fallow (Aronsson et al., 2016) and could be very beneficial in NI climatic conditions. Finding species with a high evapotranspiration potential could be a multipronged approach not only to reduce leaching of nutrients due to enhanced soil structure, but also to decrease the percolation of water through the soil (Meyer, Bergez, Constantin, & Justes, 2018).

Lack of subsidisation was only indicated by 12% of respondents as the reason why cover cropping was not widely adopted in NI compared to GB. No respondents indicated that they did not have access to machinery capable of adopting the practice. This suggests that appropriate machinery is not a barrier to uptake. The issue of shortened growing seasons could be overcome through finding more competitive species and subsidies to encourage later sowing, as despite reduced grazing potential when planted later, such cover crops will provide environmental benefits, for example, N accumulation and retention (Hashemi, Farsad, Sadeghpour, Weis, & Herbert, 2013).

3.12 | What would you like more information on?

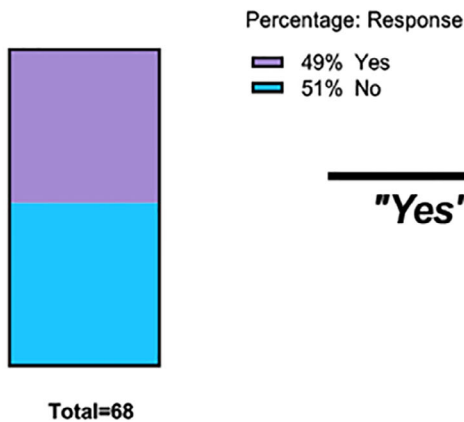
Of all respondents, 91% wanted to know more about cover crops. NI respondents indicated that they would most like to have more information on the effects of cover crops on soil health, whereas ROI respondents were most interested in the effect on yield in the subsequent crop, as increased yield could increase profitability if this outweighs sowing costs. Across all respondents, there were three common areas of interest – effect on soil health, effects of yield on the subsequent commercial crop and effects on soil structure (Figure 14). Economics was considered important and a monetary value could be calculated from further research based on the effects of cover crops on subsequent commercial crop yield.

4 | DISCUSSION

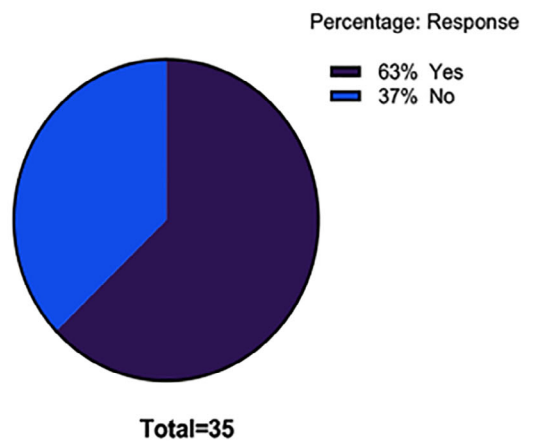
4.1 | Limitations and recommendations

The opinions shown are from stakeholders attending tillage conferences in NI and ROI (2018). These attendees could possibly be more prudent in their approach. The survey results have found that in NI there is no current method to gauge cover crop area, as mandatory land-use records focus only on commercial crop areas and omit cover

Do you receive subsidies for growing cover crops? (ROI)



Continue to grow cover crops if subsidies were removed? (ROI)



→ "Yes" Respondents

FIGURE 12 Subsidisation (ROI only). ROI, Republic of Ireland

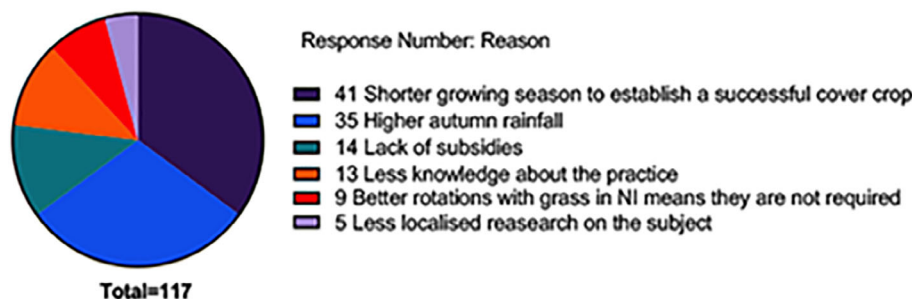


FIGURE 13 What are the biggest limitations we have for adopting cover crops (NI?). NI, Northern Ireland

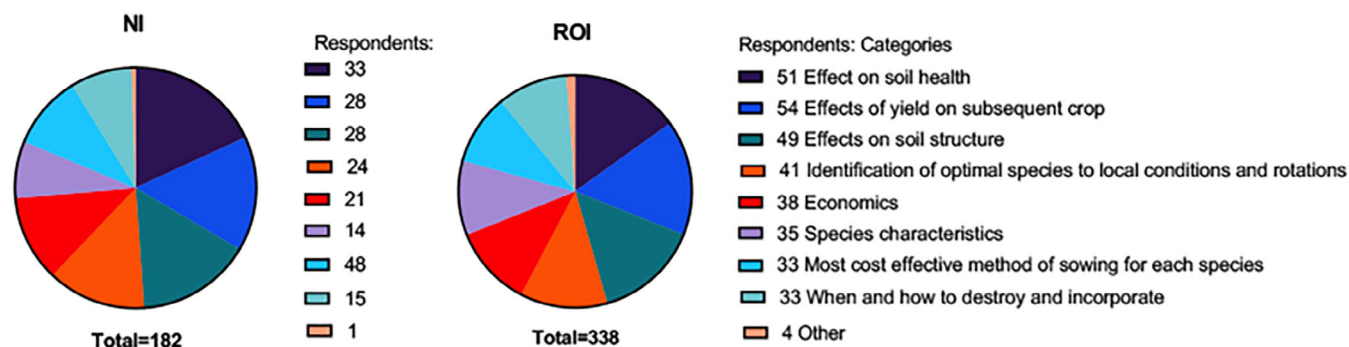


FIGURE 14 What would you like more information on?

crops. This combined with no pay-out for subsidies means there is no governmental record of land area sown to cover crops. Inclusion of land area sown as a question in this survey would have provided useful information.

It is recommended that a follow-up survey be conducted to assess changes in areas sown to cover crops and perceptions of cover crop such as functions and the benefits they present to the farm. Such a survey could also include recommendations for changes to the GLAS scheme and comments about government subsidies for cover crops in NI (and GB). The use of herbicides as the predominant method of cover crop destruction and the perception of their over-use should be included in research to identify species of cover crops which not only smother weeds during growth but also are frost killed. This would reduce the requirement for herbicides, which is particularly important to meet the ambitious target to reduce pesticides by 50% by 2030 (EC, 2020) and to reduce dependence on glyphosate. Growers who are organic may have more experience in integrating cover crops into rotations. Therefore, the addition of a section to identify these growers could provide useful insights and comparisons to conventional practice.

4.2 | Key findings

The survey shows the perception and practices gauged from a sample of the arable industry in both NI and ROI. A greater proportion of growers are using cover crops in ROI than NI due to differences in tillage area but primarily assumed to be the result of support from subsidies, particularly as provision of fodder is the main reason to grow cover crops in NI compared to improve soil health and structure in ROI. Only two respondents indicated that cover crops have no benefit to the subsequent crop or soil health, whereas the majority of respondents acknowledge their benefits as an investment in soil health.

The growers surveyed show a sound understanding of the issues posed by the loss of nutrients from land and realise that it is a significant problem on their farm. This awareness may lead to farmers being more likely to change approach and methods to help mitigate this problem as 24% and 20% of farmers, in NI and ROI respectively, are growing cover crops to reduce leaching already. Soil structure concern

was the most prevalent acknowledged problem on farms. Where growers integrate cover crops and take steps to remediate soil structure (subsoiling), increasing their investment into their land, the more likely they will be to avoid the causes of poor soil structure, for example, incorrect tillage timings and therefore take a more holistic view to the problem.

Later planting of cover crops limits their growth and reduces the potential benefits compared to earlier sowing, that is, after winter barley. NI growers are most likely to plant cover crops after early harvested crops. This is supported by the primary reason for growing them being fodder for livestock, with biomass quantity and quality being key for economic benefit and justification. In ROI, growers are more open to plant later, after crops like winter wheat and spring barley, which is encouraged by the subsidies. The result is that a greater land area is planted to cover crops in ROI, reducing the proportion of fallow land compared to NI. In ROI, where the subsidies provide monetary support, there is a greater interest in planting to improve soil health and structure and mitigate against nutrient loss. In NI, the focus is on producing fodder for livestock as growers have to economically justify cover crops use, which limits overall uptake.

There is ambiguity to the exact definitions of cover crops, catch crops, green manures: also, if fodder crops count as a true cover crops. The GLAS scheme uses the term catch crop whereas in this survey the term cover crop has been used. A survey by Jones et al. (2015) included 'grown for forage' as a reason to plant cover crops whereas Storr et al. (2019) made no mention of provision of fodder as a reason to integrate them or benefit of planting. The common goal is sustainability, where even if cover crops are grazed by livestock (provided soil and weather conditions are favourable) and residual N turned into animal protein, this is superior holistic management and use of resources compared to fallow land. Furthermore, species which are ideal for grazing such as brassicas (Keogh et al., 2012) produce high biomass resulting in large N uptakes (White, Holmes, Morris, & Stobart, 2016) and can reduce N leaching to the greatest extent (Macdonald, Poulton, Howe, Goulding, & Powlson, 2005; Shah et al., 2017; Thapa et al., 2018). The survey suggests that the effect of subsidies may increase area of cover crops grown due to economic incentives shifting grower's attention towards being more focused on soil health. This is because subsidies create a profitable crop before

benefits are taken into consideration, whereas, without subsidies grazing is the only way of getting a true on-farm economic evaluation of their effect on profitability. This is because farms cannot accurately measure economic benefits such as effect on yield, effect of soil structure and water management.

4.3 | Barriers to uptake

The two main barriers to uptake were climatic factors. Ireland has a shorter growing season compared to Great Britain and higher autumn rainfall which limits cover crop uptake. However, it is possible to discern species that are more competitive and thus better candidates to use at later sowing. This could mitigate against the shorter growing season and delayed planting caused by high rainfall. A trial with cover crops sown at various autumn dates where cover crop growth, effect on soil health (including soil structure), and the effect on yield of a subsequent commercial crop would provide the research to address the top six areas for which respondents indicated they would like more information.

Only 12% of respondents from NI indicated that lack of subsidies was a barrier to uptake, along with 63% of respondents from ROI indicating that they would continue to sow if subsidies were removed, shows that 88% of NI growers understand the observed benefits from the practice of growing cover crops. Furthermore, the effect of incentivising cover crops would boost interest and, therefore, numbers of growers incorporating the practice.

Cover crops also provide a mechanism to diversify crops being grown on a landscape scale. It is advantageous that this can be accomplished whilst maintaining the same commercial crops, and with little additional requirement for infrastructure, machinery, capital and importantly knowledge. Subsidising the practice of cover crops could change grower practice to being more likely to plant after commercial crops later than that of winter-barley and would decrease the area of over-winter fallow helping mitigate nutrient leaching specifically N, and soil degradation. Furthermore, incentivising over-winter cover crops which would be followed by a spring crop and organic manure could be an effective method to increase overall nutrient efficiency, through reduction of leaching under the cover crop and a more synchronised nutrient supply between spring applications of slurry and commercial crop growth augmenting a substantial decreased dependence on inorganic fertiliser to supply nutrients. Growers understand that planting cover crops is an investment in soil health and that benefits from cover crops are more likely to be observed over many years.

5 | GUIDING FUTURE RESEARCH

Much research conducted on cover crops is carried out in pot experiments for obvious reasons but with pendent questions about their replicable effects under field conditions, preference is given to field trials for true effects. Furthermore, little of the current research provides a holistic view including subsequent commercial crop yield and

soil health, impacts which are paramount to the most important stakeholders. The reasons for not using field trials are not only due to capital resource limitations but also due to the diminishing number of institutions that can carry out these trials as many universities do not have access to trialling facilities on the scale required.

Research conducted in the area of cover crops should focus on finding optimum species, evaluating species best suited to later sowing dates and optimising organic manure applications in conjunction with cover crops in rotations. It should investigate the effects of cover cropping on both soil and commercial crop yield and quality. There is a distinct problem of suboptimum soil structure on arable farms. Therefore, research into how cover crops can help alleviate this is important to stakeholders. Furthermore, identifying the effect of cover crops on subsequent commercial crops will help integrate cover cropping as it could economically justify the practice.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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SUPPORTING INFORMATION

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

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