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GLASTIR MONITORING & EVALUATION PROGRAMME

FINAL REPORT – Annex 4

Wales Farm Practices Survey

Legacy and Synthesis

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Abstract

*The Glastir Monitoring and Evaluation Programme (GMEP) led by the Centre for Ecology and Hydrology (CEH) is an integrated programme of whole ecosystem monitoring and modelling for robust analysis of the outcomes of the Welsh Government's Glastir agri-environment scheme (**Emmett et al., 2014**). This third and final report on the second Wales Farm Practices Survey provides a synthesis of the main survey results on the effects of Glastir on land management for diffuse pollution control and the strategic objectives of the Glastir scheme. We also present a comparison with the earlier first survey that was carried out when the preceding Tir Cynnal and Tir Gofal schemes were still operational (**Anthony, 2012**). The first survey was stratified in a similar way to the latest survey enabling questions explicitly relating to the differences in changes in nutrient and stock numbers and differences in uptake of management plans and specific actions to be compared. The analyses focus on the change in the proportion of farms carrying out particular actions to establish whether there is evidence of trend in practice on non-scheme farms and any legacy due to participation in the previous Tir Cynnal and Tir Gofal schemes.*

1. Introduction

A survey of changing farm practices associated with participation in the Glastir and preceding Tir Cynnal and Tir Gofal agri-environment schemes was commissioned by Welsh Government as part of the Glastir Monitoring and Evaluation Programme (GMEP) led by the Centre for Ecology and Hydrology (CEH; **Emmett *et al*., 2014**). The first interim report documented the design of the survey and the achieved stratification, and summarised the attributes of the survey respondents – including stocking rates, land use and the physical environment (**Anthony and Stopps, 2016**). The second interim report presented the main results tables and statistical analyses of differences in management between farm types and levels of scheme participation (**Anthony *et al*., 2016**). This third report provides a limited comparison of the results with those from the first Wales Farm Practices Survey (WFPS; **Anthony *et al*., 2012**) by presenting analyses of trend in uptake on non-scheme farms and evidence for a legacy of the preceding Tir Cynnal and Tir Gofal schemes (**Section 2 to 5**), and a synthesis of the main results from the second survey explicitly relating to diffuse pollution control and the strategic objectives of the Glastir scheme (**Section 6**). A summary of the main objectives of Glastir and the preceding schemes is provided for context (**Section 1.2**).

The additional analyses presented in this report provide support for:

- Evidence of a background level of improvement in Welsh farm practice between the first and second surveys for farms not in scheme (**Section 2**);
- Evidence of a difference in the level of change in practice associated with participation in particular schemes (**Section 3**);
- Evidence of a legacy of improved practice from the previous Tir Cynnal and Tir Gofal schemes (**Section 4**);
- Evidence that farm management plans can be used as an indicator of farms with improved practice, either causally or by association (**Section 5**).

1.1 Stratification

Both the first and second Wales farm practices surveys established the percentage of in-scheme and non-scheme farms having completed management plans as a general indication of awareness and risk assessment. In addition, they both collected information on specific management actions carried out by farmers to establish the rate at which good practice was being implemented. This enabled a direct comparison between the two surveys. However, the stratification of the 'cattle and sheep' farm type differed between the two surveys. In the first survey the cattle and sheep (CS) farm type was surveyed in two sub strata defined as Lowland Cattle and Sheep (CS-LOW) and Less Favoured Area Cattle and Sheep (CS-LFA). In contrast, the second survey used sub strata defined as farms located within the Severely Disadvantaged Area of the Less Favoured Area (CS-SDA), and farms located within the Disadvantaged Areas of the Less Favoured Area combined with farms located outside the Less Favoured Area (CS-DA+CS-LOW). As there may be some differences in practice between cattle and sheep farms located within and outside of the Less Favoured Area, comparison of the surveys required that we demonstrate that the spatial distribution of farms was similar in the two surveys. **Table 1.1** summarises the proportions of surveyed cattle and sheep farms located within the Severely Disadvantaged Area of the Less Favoured Area (CS-SDA) and elsewhere (CS-DA+CS-LOW) as recorded in the 2009 and 2016 surveys. The proportions are similar and allowed for a direct comparison of the aggregate results for the cattle and sheep farm type between the two surveys.

Table 1.1 Proportion of surveyed cattle and sheep (CS) farms located within the Severely Disadvantaged Area of the Less Favoured Area (CS-SDA) and elsewhere (CS-DA+CS-LOW) as recorded in the 2009 and 2016 surveys.

Survey Year	Farm type	
	CS-DA+CS-LOW	CS-SDA
2009	62%	38%
2016	52%	48%

1.2 Agri-Environment Schemes in Wales

Agricultural and rural development in the European Union (EU) is funded under the Common Agriculture Policy (CAP). Pillar one of the CAP has transitioned to the Basic Payments Scheme that makes area based payments to farmers who keep their land in Good Agricultural and Environmental Condition (GAEC), with additional payments for compliance with certain Greening measures based on maintenance of permanent grassland, crop diversification and ecological focus areas. Pillar two of the CAP, known as the Rural Development Pillar (RDP), provides financial support to farmers to deliver environmental goods and support rural economies and communities. Agri-environment schemes in Wales are funded under Axis 2 of the RDP (Improving the Environment and the Countryside), and provide funding for farmers to manage their land in a way that benefits biodiversity and landscape features, and improves the quality of water and soil.

The Welsh Government introduced Tir Cynnal as an entry-level agri-environment scheme in 2005 which supplemented Tir Gofal, a higher-level agri-environment scheme that had been available since 1999. The Glastir sustainable land management scheme was introduced in 2012 with an entry level component (Glastir Entry) and became the single operational agri-environmental scheme in Wales in 2013 when the higher-level component (Glastir

Advanced) was made available. The Glastir scheme replaced the Tir Cynnal and Tir Gofal schemes.

1.2.1 Tir Cynnal

The Tir Cynnal (TC) scheme provided financial support to farmers to protect wildlife habitats and landscape features. The principal objectives of the scheme were to prevent erosion of biodiversity by protecting wildlife habitats; to prevent the loss of landscape character and protect features such as traditional field boundaries; and to help reduce diffuse pollution from agricultural land by identifying risks and the actions required to remove or reduce those risks. Agreements lasted for a period of 10 years, with a break clause after 5 years.

All farmers were eligible to join the TC scheme, providing that at least 5% of their farm area was classed as a semi-natural wildlife habitat, such as broadleaved woodland, scrub, heath, and unimproved and semi-improved grassland. The TC scheme included a habitat creation option to provide the farmer with the opportunity to meet the 5% condition, which had to be complied with within 12 months of entry to the scheme. According to scheme records, a total of 1,200 ha of habitat were created from the following list of options (**Welsh Assembly Government, 2009**):

- Create streamside corridors.
- Reversion of improved to semi-improved grassland.
- Create streamside corridors.
- Reversion of improved to semi-improved grassland.
- Leaving uncropped cereal margins on cereal land.
- Creating grass margins on cereal land.
- Small scale broadleaved tree planting.
- Establishing wild bird cover crop.
- Establishing crop of unsprayed roots.

The area of habitat creation was small (<0.1%) in comparison to the total area of agricultural land in Wales. Management prescriptions applied to the wildlife habitat area included: do not plough, cultivate or re-seed; do not use herbicides or pesticides other than for spot treatment of injurious weeds; do not apply any lime, fertilisers or manures; avoid the over or under-grazing; and avoid supplementary feeding practices where these cause damage to vegetation or poaching of the soil (**Welsh Assembly Government, 2005a**).

Farms in the TC scheme were also required to prepare a whole farm Resource Management Plan (RMP) identifying the actions that needed to be taken to remove the risks to the environment from their current farming practices. The RMP was a structured questionnaire that asked whether any specific issues had been observed (such as poaching or unrestricted access by livestock to watercourses) and provided a checklist of methods by which an issue could be reduced (such as providing watering points for livestock in order to protect a watercourse). The questionnaire was structured by themes: protecting and improving soil; protecting and improving water quality (manures; plant nutrients; pesticides); and avoiding air pollution (**Welsh Assembly Government, 2005d**). There was a requirement to record any issues with the actions to be taken, and to review the RMP annually. It was not necessary to submit a copy of a completed RMP, but it had to be available for inspection during compliance audits.

The TC scheme also required farmers to complete a Manure Management Plan (MMP) and a Soil Nutrient Plan (SNP). The MMP guided participants in estimating the volumes of slurry and dirty water produced, and the requirements for storage and spreading. The available

spreading area was based on limits to nitrogen application rates defined by the Water Code and preparation of a risk map that took account of soil permeability, slope and proximity to a water feature (**Welsh Assembly Government, 2005c**). The SNP then guided participants in estimating the levels of nutrients that were supplied to crops from manufactured fertiliser and from available manures. The nutrient supply was compared with a range of standard recommendations to identify over-application of fertiliser, which might result in diffuse pollution, and under-application that might result in reduced yields.

All farmers were also subject to full Cross Compliance rules (see below), and to a number of whole farm management prescriptions for the reduction of the diffuse pollution risk:

- Protect water features from damage due to leaching of manures, fertiliser and chemicals.
- Do not apply fertiliser or chemicals within 1 m of a watercourse.
- Do not apply manure or slurry within 10 m of a watercourse.
- Manage land to avoid excessive poaching of soil to the extent that it damages the environment beyond the site itself, through run-off and soil erosion leading to pollution and increased sedimentation of watercourses.
- Avoid excessive erosion of banks of watercourses and pollution of the water by livestock and where necessary control access.

The TC scheme also recommended the preparation of an Integrated Crop Management Plan (ICMP) if pesticides were used on the farm. Participants in the TC and claiming the Single Payment were exempt from the need to complete a separate Soil Assessment Record (see below under Cross Compliance), provided they adhered to the RMP obligations and updated it annually.

1.2.2 Tir Gofal

The Tir Gofal (TG) scheme provided financial support to farmers to protect and improve the landscape. The principal objectives of the scheme were to benefit farm wildlife via the positive management of existing habitats and the encouragement of habitat restoration and creation; to protect characteristic rural landscapes and promote their management and restoration; to deliver enhanced public access to the countryside; and to protect the environment by encouraging farming practices compatible with its conservation and enhancement. It was the flagship of the Welsh agri-environment schemes with optional payments for capital works available. Agreements lasted for a period of 10 years with a break clause after 5 years. Participation was competitive and involved the preparation of a whole farm management plan. The application was reviewed by a Countryside Council for Wales (CCW) project officer who in conjunction with the farmer specified what capital works and husbandry practices needed to be incorporated into the farm plan for eligibility. Capital works payments were available for: the restoration of stone walls, earth banks and hedgerows; fencing off woodland or hedgerows; landscape and historic feature management and restoration; facilities for public access; and habitat management, restoration and creation.

The scheme was mostly concerned with landscape, wildlife, archaeological and public access in its outcomes, although habitat recreation options such as creating wetlands, reed beds, and establishing streamside corridors were options that had the potential to reduce diffuse pollution. The TG scheme required compliance with mandatory management prescriptions for habitats and features, including scrub, heath, and unimproved and semi-improved grasslands. These required stock reduction on, or exclusion of animals from some habitats or features on the farm. Maximum stock rates were set for each habitat type, which

typically ranged from 0.1 to 1.0 livestock units per hectare (LSUs). The surplus stock was normally intended to be removed from the land under the TG scheme, but exceptionally it was permitted to accommodate the surplus on improved grassland. The limited stocking was intended for the management of vegetation structure and to reduce the risk of erosion. Reductions in fertiliser and manure spreading were also required for specific habitats, such as unimproved and semi-improved grassland (**Welsh Assembly Government, 2010**). Overall stocking rates and fertiliser use were not permitted to increase above the levels carried prior to entry into the TG scheme.

Voluntary payments were available for the growing of arable crops, mainly without the use of pesticides, to encourage the wildlife of arable land. The arable options included: unsprayed cereal, rape and linseed crops; winter stubbles with limited winter grazing; spring cereals or oilseed rape under-sown with grasses and legumes; unsprayed root crops followed by winter grazing; rough grass margins; uncropped fallow margin; establishment of wildlife cover crop; and conversion of arable to grassland. The total area of land affected by these options was 6,100 ha (**Welsh Assembly Government, 2009**). Voluntary area payments were also available for grassland and habitat restoration, which placed additional restrictions on the timing of grazing, cultivations and the use of fertilisers and manures. Options included the conversion of improved grassland to semi-improved grassland; conversion of semi-improved grassland to unimproved grassland; establishment of broadleaved woodland; and establishment of heathland. The total area of land affected by these voluntary options was 21,700 ha (**Welsh Assembly Government, 2009**).

In addition to the mandatory and voluntary habitat and feature prescriptions, participating farms were also required to:

- Protect water features from damage due to leaching of manures, fertiliser and chemicals.
- Avoid application of any form of fertiliser, pesticides or other chemicals within 1 m of ponds, streams and rivers (extended to a width of 10 m when using farmyard manure, slurry or other organic manures).
- Retain a 1 m wide buffer strip from the base of each field boundary without using any cultivations, fertiliser, lime, herbicides or other pesticides.
- Avoid all poaching and other stock damage to banks and waterside vegetation.

All farmers were also subject to full Cross Compliance rules (see below). The completion of a Resource Management Plan (as for Tir Cynnal; see above) (and associated MMP and SNP) was required of farms signing TG agreements from 2007 (starting in 2008). The majority (95%) of TG agreements were signed before 2008 (**Welsh Assembly Government, 2009)** hence, the requirement for a RMP was not common.

1.2.3 Glastir

The Glastir whole farm sustainable land management scheme was launched by the Welsh Government in 2012 and provides financial support to farmers and land managers across Wales to deliver environmental improvements aimed at combating climate change, improving water management, and maintaining and enhancing biodiversity. The scheme was introduced to replace previous agri-environment schemes. The principle objectives of the scheme are to manage soils to help conserve carbon stocks and reduce soil erosion; to improve water quality and reduce surface run-off; to manage water to help reduce flood risks; to conserve and enhance wildlife and biodiversity; to manage and protect landscapes and the history environment; and to create new opportunities to improve access and

understanding of the countryside (**Welsh Assembly Government, 2013**). Agreements last for a period of 5 years.

Glastir consists of five components:

1. **Glastir Entry** – designed to support the delivery of environmental benefits through a whole farm land management scheme open to all farmers and land managers across Wales.
2. **Glastir Advanced** – intended to deliver significant improvements to the environmental status of a range of habitats, species, soils and water, within mapped priority areas. Targeted policy issues include carbon management, water quantity and quality, biodiversity species and habitats, historic environment, and landscape and access. Acceptance into the advanced scheme is competitive, subject to changing priorities and budget constraints. Although in previous years farmers were required to have a Glastir Entry contract in place, this is no longer the case.
3. **Glastir Commons** – designed to provide support for the delivery of environmental benefits on common land. The options available include a closed period of 3 continuous months between November and March and minimum and maximum stocking densities with monthly diaries retained to record the movement of stock.
4. **Glastir Woodland** – designed to provide beneficial outcomes for a range of woodland types, species, soils and water by supporting farmers and landowners to create new woodland and/or manage existing woodland. No prerequisites relating to scheme participation are required to receive these funds.
5. **Glastir Efficiency Grants** – a capital grant scheme aimed at improving resources and business efficiency through investment in new technology and equipment to promote efficient use of energy, water, and manure and slurry. Any formal offer of agreement is conditional on the land already having a Glastir Entry agreement.

Unlike previous agri-environment schemes, there is no specific obligation for participants in the Glastir Entry scheme to produce a SNP or MMP. However, under the targeted element of Glastir (Glastir Advanced), participants within Priority Areas 1 and 2 to improve water quality are required to produce a MMP to prevent the over application of manure, slurry, dirty water and other organic wastes to reduce diffuse water pollution (**Welsh Assembly Government, 2015**). FACTS qualified practitioners also completed SNPs on farms applying for the Glastir Advanced scheme to prevent over application of slurry and fertiliser and to reduce nutrients leaching into watercourses (**Welsh Assembly Government, 2016**). Although the obligatory management rules associated with the previous Tir Gofal scheme were relaxed, farmers and land managers in Glastir are subject to full Cross Compliance rules (see below), and to a number of Whole Farm Code management prescriptions for the reduction of the diffuse pollution risk. These included:

- Maintain field records of all applications of farmyard manures, slurry, inorganic fertiliser, organic fertiliser, calcified seaweed, lime, sewage sludge, waste paper sludge, other off and on-farm wastes, pesticides and herbicides.
- Do not plough or cultivate any land within 2 meters of a watercourse or a wetland habitat.
- Do not apply livestock manures and dirty water when the soil is waterlogged or frozen hard.
- Manure, silage or other farm wastes must not be stored on a flood risk area (1 in 100 year risk) or a high-risk slope of over 7°.
- Where maize is grown, the risk of soil erosion must be reduce by undertaking one of the following:
    - Chisel plough post-harvest to reduce compaction;
    - Under sow crop with ryegrass;

- Break up compaction made by tractor wheeling using fixed tine and establish a winter crop.

The Glastir scheme also required participants to conform to rules applicable to all habitat land. These included:

- Do not damage habitat land through over or under grazing and poaching caused by stock feeding and rutting by vehicles.
- Habitat land must not be agriculturally improved, with the exception of bracken control.
- Do not plough, cultivate or re-seed the habitat land, including roll or chain harrow between 15th March and 15th July.
- Do not install new drainage or modify existing drainage.
- Do not clear ditches between 1st March and 31st August.
- Do not apply slurry, inorganic fertilisers, organic fertilisers, farmyard manure or other off and on-farm wastes on habitat land.
- Manure, silage or other farm wastes must not be stored within 10 meters of any watercourse.
- Do not use herbicides except to spot treat and control notifiable weeds or invasive alien species.

In addition to complying with Cross Compliance and Whole Farm Code, participants within the Glastir scheme are required to undertake a number of management options best suited to their farms. Management options are assigned scores and acceptance into scheme is dependent on achieving a minimum total score. The option scores are assigned weights in certain mapped priority areas to encourage uptake of options that address targeted policy issues.

1.2.4 Cross Compliance

Adherence to Cross Compliance, which sets standards that farmers have to meet in order to receive Common Agricultural Policy (CAP) payments, is necessary for the receipt of the Basic Payment Scheme (BPS) and applies to all of those participating in the Welsh agri-environment schemes. Cross Compliance comprises two elements: adherence to a Statutory Management Requirement (SMR); and a requirement to keep land in Good Agricultural and Environmental Condition (GAEC). The most relevant requirements for diffuse pollution control are the GAECs which comprise of seven compulsory standards:

- **GAEC 1 Water – establishment of buffer strips:**
  To protect surface water from pollution and run-off from agricultural sources by creating buffer strips.
- **GAEC 2 Water – use of water for irrigation:**
  To protect water resources by licencing abstraction of water for irrigation to ensure flows are maintained to befit all water users, the environment and biodiversity.
- **GAEC 3 Water – groundwater:**
  To protect groundwater from agricultural pollution.
- **GAEC 4 Soil and carbon stock – minimum soil cover.**
  To minimalise soil erosion by requiring a minimum soil cover.
- **GAEC 5 Soil and carbon stock – minimum land management site specific conditions to limit erosion:**
  To limit soil erosion by not undertaking certain operations.
- **GAEC 6 Soil and organic matter – maintenance:**

To protect the soil and provide environmental benefits of maintaining habitats and biodiversity.

- **GAEC 7 Maintenance of landscape features:**
  To protect landscape features and scheduled monuments, providing historical and cultural value in addition to providing valuable shelter for livestock, nesting cover for birds and a variety of habitats for wildlife.

The GAEC standards aim to ensure that farmers protect the three main elements of the farmed environment: soil and water; habitats and wildlife; and landscape features. GAECs 1-3 relate to the protection of water against pollution and runoff and management of the use of water. GAECs 4-6 relate to the protection of soil through ensuring a minimum soil cover, prevention of soil erosion and maintenance of soil organic matter levels. GAEC 7 relates to the retention of landscape features and avoiding habitat deterioration.

Since the Single Farm Payment was replaced by the BPS in 2015, cross compliance soil management rules have changed considerably. The most notable change concerns the previous requirement under GAEC to complete and retain a Soil Protection Review (SPR) or soil assessment record. This is no longer a requirement and has been replaced by a new set of national minimum standards. Other important changes relating to diffuse pollution control include: the prohibition in the use of pesticides within 2 meters of a watercourse unless a permit is obtained from Natural Resources Wales; to install sediment fencing or chisel ploughing to prevent erosion on late harvested land where it is not possible to sow a cover crop; and completion to a soil risk assessment is rough ploughed land is left between harvest and 1st March the following year.

Cross Compliance has generally raised awareness of diffuse pollution issues. Enforcement is by random inspection or a proportion of holdings by Government officials who can impose penalties on the BPS payment if there are breaches.

2. Change in Management on Non-Scheme Farms (2009 to 2016)

Objective*: Is there any evidence for a background level of improvement in Welsh farm practice outside of scheme participation between 2009 and 2016?*

Over the past decade there has been a considerable effort to provide advice and guidance to farmers and land managers with the aim of encouraging good agricultural practice in order to improve farm business sustainability and to minimise the risks of diffuse air and water pollution. This has been delivered through a number of whole country initiatives and campaigns. For example, a Catchment Sensitive Farming Demonstration Project was commissioned in three catchments within Wales between 2006 and 2008 with the intention of raising awareness of catchment-sensitive farming issues. To support farmers in action to reduce risk of water pollution from farms, the scheme delivered capital works on farms and advice to farmers. The Code of Good Agricultural Practice for the protection of water, soil and air for Wales (**Welsh Assembly Government, 2011**) is a practical guide that provides advice and guidance to farmers and land managers on good agricultural practice. Good practice is defined as that which reduces the risk of pollution, while allowing profitable and productive farming to continue. The Fertiliser Manual (RB209) (**Defra, 2010**), is a manual to help farmers and land managers to better assess the fertiliser required for the range of crops they plan to grow and to help prevent over-application. Furthermore, Natural Resources Wales also offers advice on ways to help farmers protect the environment and comply with environmental legislation, including temporary guidance to help farmers manage nutrients following wet weather.

More recently, there has been guidance produced from within the agricultural sector such as 'Tried and Tested' which works with Catchment Sensitive Farming and the Campaign for the Farmed Environment at a national level to facilitate the delivery of clear and consistent local environmental messages to farmers. Farmers are encouraged to improve nutrient management planning through a toolkit of practical nutrient, manure and feed planning guidance. Free nutrient management planning is offered to assist farmers and advisors to improve whole farm nutrient management in an environmentally friendly, cost effective and practical way.

In order to establish whether there has been a general degree of improvement in Welsh farm practices without the complicating effects of scheme, we compared first (2009) and second (2016) WFPS respondents that had no history of participation in any of the Welsh agri-environment schemes. Both surveys recorded the percentage of non-scheme farms having completed management plans as a general indication of awareness and risk assessment, and collected information on specific management actions carried out by farmers to establish the rate of which good practice was being implemented.

2.1 Manure Management

The Code of Good Agricultural Practice (**Welsh Assembly Government, 2011**) encourages farmers to prepare a MMP and update it regularly. **Table 2.1** summarises the percent of non-scheme farms completing a manure management plan (MMP) in 2009 and 2016, stratified by farm type. There was a significant increase in the percent of CS farms completing a MMP between 2009 and 2016. The calculated marginal effect was 24.6% (*generalised linear model*, $P < 0.01$) (**Table 2.2**). In contrast, the level of increase seen in the number of DAIRY farms completing a MMP was small compared to the baseline and was not statistically significant (**Table 2.1**).

Table 2.3 summarises the average total number of manure management actions taken by non-scheme farmers and the percent of respondents taking specific actions in 2009 and 2016. The average number of actions implemented by CS and DAIRY farms increased between 2009 and 2016. This increase in the overall number of manure management actions undertaken on CS farms was statistically significant (*generalised linear model*, P < 0.01). In general CS farms carried out 0.52 more total actions in 2016 (**Table 2.4**). The increase in the overall number of actions undertaken on DAIRY farms was not significant (*generalised linear model*, P > 0.05).

The percent of CS and DAIRY farms claiming to have carried out individual management actions generally increased between 2009 and 2016 (**Table 2.3**). The increase in the uptake of three specific actions on CS farms during this time period were statistically significant (**Table 2.4**). These actions were relatively simple to implement and involved a low capital cost. The action with the greatest marginal effect (14.4%) was '*separating dirty yard water from runoff from clean concrete and roofs*' (*generalised linear model*, P <0.01). Under Farming Connect, which supports farm businesses in Wales to improve business performance and long-term sustainability, clean and dirty water separation is encouraged through 'simple, cost-effective solutions' (**Farming Connect, 2011)**. The marginal effects of the other significant manure management actions were 12.3% for '*moving manure heaps away from watercourse*' (*generalised linear model*, P 0.02) and 9.7% for '*reducing water usage for watering or cleaning livestock an buildings*' (*generalised linear model*, P 0.03) respectively.

Statistical modelling established that the increase in uptake of two specific actions on DAIRY farms between 2009 and 2016 were significant (**Table 2.4**). As with the CS farm type, these actions were relatively simple to implement and involved little capital cost. These actions involved '*moving manure heaps away from watercourse*' and '*calibrating manure spreader*', with calculated marginal effects of 29.9% (*generalised linear model*, P 0.03) and 18.7% (*generalised linear model*, P 0.04) respectively. The Tried and Tested guide to manure management (**Environment Agency, 2011**) states that where solid manure is stored in a field heap it should not be sited within 10 meters of a watercourse. In addition, the Code of Good Agricultural Practice (**Welsh Assembly Government, 2011**) states that all equipment should be checked, maintained and calibrated at least once a year. The other management actions did not show any significant change between 2009 and 2016.

Table 2.1 Percent of survey respondents completing a manure management plan, soil nutrient management plan and soil assessment or protection plan in the 2009 and 2016 surveys for farms that have never participated in an agri-environment scheme, stratified by farm type.

Management plan	Survey	CS	DAIRY
Manure management plan	**2009**	31.6 (24.7 to 39.1) *n* 174	83.0 (73.9 to 89.8) *n* 88
	2016	56.2 (46.7 to 64.8) *n* 105	86.8 (76.3 to 97.4) *n* 38
Soil nutrient management plan	**2009**	21.7 (14.8 to 28.7) *n* 115	51.8 (42.2 to 62.7) *n* 83
	2016	34.2 (24.1 to 45.6) *n* 79	55.9 (38.2 to 73.5) *n* 34
Soil assessment or protection plan	**2009**	68.6 (61.7 to 76.0) *n* 175	72.2 (62.2 to 82.2) *n* 90
	2016	44.0 (33.0 to 53.8) *n* 91	65.7 (48.6 to 80.0) *n* 35

Table 2.2 Coefficients and marginal effects of binomial model fitted to the proportion of non-scheme CS and DAIRY farms completing management plans in the 2009 and 2016 surveys.

Binomial Model Coefficients and Marginal Effects						
CS Farm Type						
Completed a manure management plan		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.772	0.163	-4.733	<0.01
		Year_16	1.021	0.255	3.995	<0.01
		AIC:	365.06			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.246	0.06	4.104	<0.01
Completed a soil assessment or protection plan		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.780	0.163	4.791	<0.01
		Year_16	-1.023	0.267	-3.836	<0.01
		AIC:	346.69			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.246	0.063	-3.922	<0.01
DAIRY Farm Type						
Completed a soil assessment or protection plan		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.379	0.186	7.397	<0.01
		Year_16	-0.949	0.313	-3.026	<0.01
		AIC:	272.20			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.193	0.067	-2.870	<0.01

Table 2.3 Average count of all manure management actions taken by non-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 surveys, stratified by farm type.

	Survey	CS	DAIRY
Count of all actions (n)	2009	1.4 (1.3 to 1.6) *n* 174	2.6 (2.2 to 3.0) *n* 88
	2016	1.8 (1.6 to 1.7) *n* 105	3.0 (2.5 to 3.6) *n* 38
Increased size of slurry store (%)	2009	2.3 (0.6 to 4.6)	18.2 (11.4 to 26.1)
	2016	2.9 (0.0 to 5.7)	21.1 (10.5 to 34.2)
Bought or rented more land to spread manure (%)	2009	5.7 (2.3 to 9.8)	27.3 (18.2 to 36.4)
	2016	1.9 (0.0 to 4.8)	21.1 (10.5 to 34.2)
Exported excess manure to another holding (%)	2009	0.0 (0.0 to 0.0)	6.8 (2.3 to 12.5)
	2016	1.0 (0.0 to 2.9)	7.9 (0.0 to 18.4)
Roofed yard areas (%)	2009	8.6 (4.6 to 13.2)	19.3 (11.4 to 28.4)
	2016	7.6 (2.9 to 13.3)	13.2 (2.6 to 23.7)
Separated 'dirty' yard water from runoff from clean concrete and roofs (%)	2009	16.1 (10.9 to 22.4)	52.3 (42.0 to 62.5)
	2016	30.5 (21.9 to 39.0)	63.2 (47.4 to 78.9)
Reduced water usage for watering or cleaning livestock and buildings (%)	2009	10.3 (6.3 to 14.9)	33.0 (23.9 to 43.2)
	2016	20.0 (13.3 to 27.6)	36.8 (21.1 to 52.6)
Covered manure heaps (%)	2009	2.3 (0.6 to 4.6)	5.7 (1.1 to 11.4)
	2016	5.7 (1.9 to 10.5)	7.9 (0.0 to 15.8)
Moved manure heaps away from watercourse (%)	2009	14.4 (9.8 to 20.1)	22.7 (13.6 to 31.8)
	2016	26.7 (18.1 to 35.2)	52.6 (36.8 to 68.4)
Calibrated manure spreader (%)	2009	8.6 (4.6 to 12.6)	18.2 (11.4 to 26.1)
	2016	14.3 (7.6 to 21.9)	36.8 (23.7 to 52.6)
Increased proportion of manures spread during spring or growing season (%)	2009	20.1 (14.4 to 26.4)	52.3 (42.0 to 62.5)
	2016	30.5 (21.9 to 40.0)	36.8 (23.6 to 52.6)

Table 2.4 Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken by non-scheme CS and DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
CS Farm Type						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.122	0.081	-1.515	>0.1
		Year_16	0.465	0.115	4.043	<0.01
		AIC:	882.182			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.524	0.136	3.855	<0.01

Table 2.4 *cont.* Coefficients and marginal effects of binomial model fitted to the proportion of non-scheme CS and DAIRY respondents taking specific manure management actions in the 2009 and 2016 surveys.

Binomial Model Coefficients and Marginal Effects						
CS Farm Type						
Separated 'dirty' yard water from runoff from clean concrete and roofs		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.651	0.206	-8.004	<0.01
		Year_16	0.827	0.296	2.794	<0.01
		AIC:	286.652			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.144	0.053	2.721	<0.01
Reduced water usage for watering or cleaning livestock and buildings		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.159	0.249	-8.676	<0.01
		Year_16	0.773	0.349	2.218	0.03
		AIC:	224.827			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.097	0.045	2.129	0.03
Moved manure heaps away from watercourse		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.785	0.216	-8.259	<0.01
		Year_16	0.773	0.309	2.504	0.01
		AIC:	269.014			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.123	0.051	2.426	0.02
DAIRY Farm Type						
Moved manure heaps away from watercourse		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.224	0.254	-4.811	<0.01
		Year_16	1.329	0.413	3.221	<0.01
		AIC:	150.903			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.299	0.093	3.233	<0.01
Calibrated manure spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.504	0.276	-5.442	<0.01
		Year_16	0.965	0.435	2.217	0.03
		AIC:	137.465			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.187	0.088	2.111	0.04

2.2 Nutrient Management

Table 2.1 summarises the percent of non-scheme farms completing a nutrient management plan (NMP) in 2009 and 2016, stratified by farm type. There was a small increase in the number of non-scheme farms completing NMPs in 2016 in comparison to the first survey, but the change was not statistically significant on either the CS or DAIRY farm type.

The average total number of nutrient management actions implemented by non-scheme CS and DAIRY farms increased between 2009 and 2016 (**Table 2.5**). This increase in the overall number of actions undertaken on CS farms was statistically significant (*generalised linear model*, $P < 0.01$). In general CS farms carried out 0.76 more total actions in 2016 (**Table 2.6**). The increase in the overall number of actions undertaken on DAIRY farms was not significant (*generalised linear model*, $P > 0.05$).

The proportion of CS and DAIRY farms claiming to have carried out individual nutrient management actions generally increased between 2009 and 2016 (**Table 2.5**). Statistical modelling established that the increase in uptake of specific management actions by CS farms involving '*calibration of fertiliser spreader*', '*using a fertiliser recommendation system*' and '*testing of soil nutrient status*' were statistically significant (**Table 2.6**). These actions concerned activities relating to the improvement of farm business through more efficient use of nutrient inputs that were relatively simple to implement and involved little capital cost. The marginal effects ranged from 23.7% for '*testing of soil nutrient status*' (*generalised linear model*, $P <0.01$) to 13.6% for '*calibrating fertiliser spreader*' (*generalised linear model*, P 0.05). There was no significant change in the implementation of actions involving '*increasing use of straight rather than compound fertiliser*' and '*delaying application to avoid spreading to wet or frozen ground'* by non-scheme CS farmers during this period. The actions that have significantly increased specifically relate to the advice and guidance provided to farmers and land managers. For example, the Code of Good Agricultural Practice (**Welsh Assembly Government, 2011**) states that as part of having a nutrient management plan in place, soils should be analysed every three to five years to assess nutrient status and that the nutrient requirements of crops should be assessed using a recognised fertiliser recommendation system such a Defra's RB209. The RB209 states that farmers should "*regularly maintain and calibrate fertiliser spreaders and sprayers*" and "*use a recognised nutrient recommendation system*" to make best economic use of nutrients (**Defra, 2009**). Furthermore, the Tried and Tested initiative encourages farmers to complete a soil nutrient plan which would require them to regularly test soil nutrient status.

As with manure management actions, the implementation of individual nutrient management actions was generally higher on DAIRY farms in comparison with the CS farm type. Statistical modelling established that the percent of non-scheme DAIRY farmers carrying out the nutrient management action involving '*calibrating fertiliser spreaders*' significantly increased in 2016 in comparison with the 2009 survey. The calculated marginal effect was 27.6% (*generalised linear model*, $P < 0.01$). In contrast with the CS farm type, there was a significant increase in the implementation of the action involving '*increasing use of straight rather than compound fertiliser'*, with a marginal effect of 19.4% (*generalised linear model*, P 0.04) (**Table 2.6**).The other management actions implemented by DAIRY farmers did not show any significant change during this 7 year period.

Table 2.5 Average count of all nutrient management actions taken by non-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 surveys, stratified by farm type.

	Survey	CS	DAIRY
Count of all actions (n)	2009	1.3 (1.1 to 1.5) n = 117	2.4 (2.1 to 2.8) n = 85
	2016	2.1 (1.7 to 2.4) n = 79	3.1 (2.6 to 3.5) n = 34
Calibration of the fertiliser spreader (%)	2009	25.6 (17.9 to 33.3)	45.9 (36.5 to 56.5)
	2016	39.2 (29.1 to 50.6)	73.5 (58.8 to 88.2)
Testing of soil nutrient status (%)	2009	25.6 (17.9 to 34.2)	60.0 (49.4 to 69.4)
	2016	49.4 (38.0 to 60.8)	70.6 (52.9 to 85.3)
Use a fertiliser recommendation system (%)	2009	13.7 (7.7 to 20.5)	43.5 (32.9 to 54.1)
	2016	32.9 (24.1 to 44.3)	58.8 (41.2 to 76.5)
Increased use of straight rather than compound fertiliser (%)	2009	8.5 (3.4 to 13.7)	18.8 (11.8 to 27.1)
	2016	17.7 (10.1 to 26.6)	38.2 (20.6 to 52.9)
Delayed application to avoid spreading to wet of frozen ground (%)	2009	55.6 (47.0 to 65.0)	76.5 (68.2 to 84.7)
	2016	65.8 (55.7 to 77.2)	64.7 (50.0 to 79.4)

Table 2.6 Coefficients and marginal effects of poisson and binomial models fitted to the total count of nutrient management actions taken by non-scheme CS and DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
CS Farm Type						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.255	0.081	3.135	<0.01
		Year_16	0.463	0.113	4.094	<0.01
		AIC:	614.397			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.760	0.192	3.925	<0.01
Binomial Model Coefficients and Marginal Effects						
CS Farm Type						
Calibration of fertiliser spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.065	0.212	-5.029	<0.01
		Year_16	0.627	0.313	2.005	0.05
		AIC:	243.039			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.136	0.068	1.995	0.05

Table 2.6 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of nutrient management actions taken by non-scheme CS and DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Testing of soil nutrient status		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.065	0.212	-5.029	<0.01
		Year_16	1.039	0.309	3.364	<0.01
		AIC:	246.713			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.237	0.069	3.427	<0.01
Use a fertiliser recommendation system		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.843	0.269	-6.848	<0.01
		Year_16	1.130	0.360	3.138	<0.01
		AIC:	197.472			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.192	0.062	3.199	<0.01
DAIRY Farm Type						
Calibration of fertiliser spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-0.165	0.218	-0.758	>0.10
		Year_16	1.187	0.446	2.664	<0.01
		AIC:	160.557			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.276	0.093	2.973	<0.01
Increased use of straight rather than compound fertiliser		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.462	0.277	-5.267	<0.01
		Year_16	0.982	0.449	2.187	0.03
		AIC:	131.455			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.194	0.094	2.076	0.04

2.3 Soil Management

Table 2.1 summarises the percent of non-scheme farms completing a soil assessment or protection plan in 2009 and 2016, stratified by farm type. There were fewer CS and DAIRY farms completing a soil assessment or protection plan in 2016 compared to the first survey. Statistical modelling confirmed that this decrease was statistically significant for both farm types, indicating a significant background change in management on non-scheme farms between 2009 and 2016. The calculated marginal effect was 24.6% for CS farms and 19.3% for DAIRY farms (*generalised linear model*, P <0.01) (**Table 2.2**). Under the previous Cross Compliance rules, in order for farmers to receive their Single Farm Payment, a Soil Protection Review was required under GAEC1. Since 2015 when the Single Farm Payment was replaced by the Basic Payment Scheme, the GAECs were updated and the obligation to complete and retain a Soil Protection Review was no longer a specific requirement. Therefore, it was expected that a greater number of farmers would have completed a soil

assessment or protection plan in 2009 compared to when the second survey was undertaken in 2016.

Table 2.7 summarises the average total number of soil management actions taken on grassland fields by non-scheme farmers and the percent of respondents taking specific actions in 2009 and 2016. In contrast to the uptake of soil assessments or protection plans, the total number of actions undertaken on grassland fields by both CS and DAIRY farms significantly increased between 2009 and 2016 (*generalised linear model*, P <0.01). This suggests that there was an improvement in management on non-scheme farms between 2009 and 2016, and that completion of a management plan is not a prerequisite. In general CS and DAIRY farms carried out 0.74 and 1.73 more total actions in 2016 respectively (**Table 2.8**).

The percent of CS and DAIRY farms claiming to have carried out individual grassland soil management actions generally increased between 2009 and 2016 (**Table 2.7**). However, only 2 specific management actions carried out by non-scheme CS farms exhibited a significant change in implementation during this time period (*generalised linear model*, P <0.01). These actions involved '*reducing stocking rate on fields subject to poaching*' and '*re-siting or regularly rotating feeding sites*', with calculated marginal effects of 17.5 and 22% respectively (**Table 2.8**). Under the Cross Compliance rules, farmers are required to minimise soil erosion caused by livestock management under GAEC 5. They are specifically encouraged to adjust stocking rates to conserve vegetation cover (**Defra, 2015**) and regularly move feed locations (**Welsh Assembly Government, 2015**).

Significant increases in the percent of farms carrying out a management action were recorded for a majority of actions on the DAIRY farm type. The calculated marginal effects ranged from 20.6% for '*re-siting or regularly rotating feeding sites*' (*generalised linear model*, P 0.04) to 44% for '*removing compaction by re-seeding or soil loosening*' (*generalised linear model*, P <0.01) (**Table 2.8**). There were 3 management actions that showed either a significant decrease in implementation or no significant change. These actions concerned activities that have an impact on the overall day-to-day running of the farm business and could therefore be seen as a less attractive option to implement for DAIRY farms. The implementation of the management action that requires farmers to '*no longer out-winter cattle*' significantly decreased between 2009 and 2016, with a marginal effect of 21.7% (*generalised linear model*, P 0.03). The management actions concerning '*reducing the length of grazing season or day*' and '*delaying putting stock out to grass*' did not show any significant change between 2009 and 2016 (**Table 2.7**).

Table 2.9 summarises the average total number of soil management actions taken on arable fields by non-scheme farmers and the percent of respondents taking specific actions in 2009 and 2016. There was no statistically significant change for either the CS or DAIRY farm types (*generalised linear model*, P >0.05). Note that the limited number of respondents for the DAIRY farm type means that these results for arable soil management should be treated with some caution.

Only 1 specific action showed a significant increase in uptake over this time period, and this was for the non-scheme DAIRY farms. This action concerned '*leaving stubble in field*', with a calculated marginal effect of 38% (*generalised linear model*, P <0.01) (**Table 2.10**). This action is one of the requirements under Cross Compliance. Farmers are encouraged to protect the soil by having a minimum soil cover under GAEC4 (**Welsh Assembly Government, 2014**). Leaving stubble of the harvested crop on the land between the day after harvest and March is one condition that farmers are encouraged to meet. Furthermore, the Code of Good Agricultural Practice (**Welsh Assembly Government, 2011**) states that

farmers should leave the land in stubble where it is not possible to establish a cover crop. However, statistical modelling also established that there was a decrease in implementation of 1 specific soil management action undertaken by non-scheme CS farms between 2009 and 2016. This action involved '*establishing winter cover by early drilling*', with a calculated marginal effect of 24.8% (*generalised linear model*, P 0.03) (**Table 2.10**).

Table 2.7 Average count of all soil management actions taken on grassland fields by non-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 surveys, stratified by farm type.

	Survey	CS	DAIRY
Count of all actions (n)	2009	3.5 (3.1 to 3.8) n = 174	4.0 (3.4 to 4.5) n = 90
	2016	4.2 (3.8 to 4.7) n = 89	5.7 (5.0 to 6.4) n = 33
Delayed putting stock out to grass (%)	2009	56.3 (48.9 to 63.2)	71.1 (62.2 to 81.1)
	2016	55.1 (44.9 to 66.3)	78.8 (66.6 to 90.9)
Reduced stocking rate on fields subject to poaching (%)	2009	44.3 (37.4 to 52.3)	50.0 (40.0 to 60.0)
	2016	61.8 (52.8 to 71.9)	72.7 (57.6 to 87.9)
Reduced length of grazing season or day (%)	2009	34.5 (27.6 to 41.4)	40.0 (28.9 to 50.0)
	2016	44.9 (34.8 to 55.1)	54.5 (36.4 to 69.7)
Improved drainage on poached fields (%)	2009	21.3 (16.1 to 27.0)	26.7 (17.8 to 34.4)
	2016	30.3 (21.3 to 40.4)	51.5 (33.3 to 69.7)
Remove compaction by re-seeding or soil loosening (%)	2009	36.2 (29.3 to 43.7)	37.8 (28.9 to 47.8)
	2016	44.9 (34.8 to 55.1)	81.8 (66.7 to 93.9)
Fenced off streams from livestock (%)	2009	23.0 (16.7 to 29.3)	28.9 (20.0 to 38.9)
	2016	28.1 (19.1 to 38.2)	57.6 (42.4 to 72.7)
Provided in-field watering points (%)	2009	48.3 (41.4 to 55.2)	41.1 (31.1 to 51.1)
	2016	50.6 (40.4 to 60.7)	72.7 (57.6 to 87.9)
Re-sited or regularly rotated feeding sites (%)	2009	47.7 (39.7 to 55.2)	40.0 (30.0 to 50.0)
	2016	69.7 (59.6 to 79.8)	60.6 (42.4 to 75.8)
No longer out-winter cattle (%)	2009	35.1 (28.2 to 42.0)	61.1 (51.1 to 71.1)
	2016	34.8 (24.7 to 43.8)	39.4 (21.2 to 57.6)

Across all types of management plan, statistical modelling established that there were significant (*generalised linear model*, P <0.05) increases in the rate of uptake of 18 individual management actions between 2009 and 2016 on non-scheme farms. The increases were distributed between manure management (5 of 20), nutrient management (5 of 10) and soil management (11 of 44) possible actions analysed separately for dairy and cattle & sheep farms, which supports the conclusion that there is evidence for some improvement in management on non-scheme farms between 2009 and 2016.

Table 2.8 Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on grassland fields by non-scheme CS and DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
CS Farm Type						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.243	0.041	30.520	<0.01
		Year_16	0.193	0.066	2.929	<0.01
		AIC:	1198.765			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.737	0.259	2.843	<0.01
DAIRY Farm Type						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.378	0.053	26.035	<0.01
		Year_16	0.362	0.090	4.017	<0.01
		AIC:	588.176			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	1.730	0.466	3.717	<0.01
Binomial Model Coefficients and Marginal Effects						
CS Farm Type						
Reduced stocking rate on fields subject to poaching		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.231	0.153	-1.513	>0.10
		Year_16	0.712	0.266	2.674	<0.01
		AIC:	361.289			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.175	0.064	2.750	<0.01
Re-sited or regularly rotated feeding sites		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.092	0.152	-0.606	>0.10
		Year_16	0.923	0.276	3.345	<0.01
		AIC:	354.085			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.220	0.062	3.559	<0.01
DAIRY Farm Type						
Reduced stocking rate on fields subject to poaching		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.000	0.211	0.000	>0.10
		Year_16	0.981	0.444	2.209	0.03
		AIC:	167.439			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.227	0.094	2.424	0.02

Table 2.8 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on grassland fields by non-scheme CS and DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Improved drainage on poached fields		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.012	0.238	-4.244	>0.01
		Year_16	1.072	0.422	2.540	0.01
		AIC:	154.102			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.248	0.099	2.518	0.01
Remove compaction by re-seeding or soil loosening		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.499	0.217	-2.295	0.02
		Year_16	2.003	0.501	3.998	<0.01
		AIC:	154.627			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.440	0.084	5.219	<0.01
Fenced off streams from livestock		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.901	0.233	-3.873	<0.01
		Year_16	1.206	0.422	2.858	<0.01
		AIC:	157.195			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.287	0.098	2.915	<0.01
Provided in-field watering points		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.359	0.214	-1.678	>0.10
		Year_16	1.340	0.446	3.007	<0.01
		AIC:	164.580			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.316	0.093	3.390	<0.01
Re-sited or regularly Rotated feeding sites		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.405	0.215	-1.884	>0.05
		Year_16	0.836	0.416	2.009	0.05
		AIC:	169.394			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.206	0.100	2.071	0.04
No longer out-winter cattle		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.452	0.216	2.090	0.04
		Year_16	-0.883	0.417	-2.118	0.03
		AIC:	168.536			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.217	0.099	-2.185	0.03

Table 2.9 Average count of all soil management actions taken on arable fields by non-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 surveys, stratified by farm type.

	Survey	CS	DAIRY
Count of all actions (n)	2009	3.7 (2.7 to 4.7) n = 39	4.1 (3.2 to 5.1) n = 36
	2016	3.7 (2.6 to 4.8) n = 31	5.5 (3.6 to 7.3) n = 13
Established winter cover by early drilling (%)	2009	53.8 (38.5 to 69.2)	25.0 (11.1 to 41.7)
	2016	29.0 (12.9 to 45.2)	38.5 (15.4 to 69.2)
Leave stubble in field (%)	2009	25.6 (12.8 to 38.6)	38.9 (22.2 to 55.6)
	2016	38.7 (22.6 to 54.8)	76.9 (46.2 to 100)
Established winter cover by sowing cover crop (%)	2009	30.8 (15.4 to 46.2)	38.9 (22.2 to 55.6)
	2016	45.2 (29.0 to 61.3)	38.5 (15.4 to 69.2)
Delayed field operations to avoid working on wet soil (%)	2009	64.1 (48.7 to 79.5)	77.8 (63.9 to 88.9)
	2016	58.1 (38.7 to 74.2)	84.6 (61.5 to 100)
Used minimal cultivation techniques (%)	2009	28.2 (15.4 to 41.0)	19.4 (8.3 to 33.3)
	2016	38.7 (22.6 to 58.1)	7.7 (0.0 to 23.1)
Rough ploughing to remove harvest compaction (%)	2009	25.6 (12.8 to 41.0)	25.0 (11.1 to 38.9)
	2016	35.5 (19.4 to 51.6)	38.5 (15.4 to 61.5)
Loosened or disrupted compacted tramlines (%)	2009	17.9 (7.7 to 30.8)	27.8 (13.9 to 44.4)
	2016	16.1 (6.5 to 29.1)	53.8 (30.8 to 76.9)
Delayed tramline establishment (%)	2009	12.8 (2.6 to 23.1)	8.3 (0.0 to 16.7)
	2016	9.7 (0.0 to 22.6)	15.4 (0.0 to 38.5)
Delayed cultivation for spring sown crops until the spring (%)	2009	38.5 (23.1 to 53.8)	50.0 (33.3 to 64.0)
	2016	45.2 (25.8 to 61.3)	76.9 (53.8 to 100)
Left autumn seed beds rough (%)	2009	17.9 (7.6 to 30.8)	41.7 (25.0 to 58.3)
	2016	12.9 (3.2 to 25.8)	30.8 (7.7 to 61.5)
Cultivating across slope (%)	2009	20.5 (7.7 to 33.3)	27.8 (13.8 to 41.7)
	2016	16.1 (3.2 to 32.3)	23.1 (0.0 to 46.2)
Established vegetated and uncultivated buffer strip (%)	2009	10.3 (2.6 to 20.5)	13.9 (5.6 to 25.1)
	2016	6.5 (0.0 to 16.1)	23.1 (0.0 to 46.4)
Convert field corners to grass or bird cover (%)	2009	20.5 (7.7 to 33.3)	19.4 (8.3 to 33.3)
	2016	16.1 (6.5 to 29)	30.8 (7.7 to 61.5)

Table 2.10 Coefficients and marginal effects of binomial model fitted to the proportion of respondents taking specific soil management actions on arable fields by non-scheme CS and DAIRY farms in the 2009 and 2016 surveys.

Binomial Model Coefficients and Marginal Effects						
CS Farm Type						
Established winter cover by early drilling		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.154	0.321	0.480	>0.10
		Year_16	-1.048	0.510	-2.056	0.04
		AIC:	95.186			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.248	0.114	-2.175	0.03
DAIRY Farm Type						
Leave stubble in field		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.452	0.342	-1.322	>0.10
		Year_16	1.656	0.742	2.232	0.03
		AIC:	66.159			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.380	0.142	2.672	<0.01

There is evidence for a background level of improvement in Welsh farm practices between 2009 and 2016. This is particularly the case for manure management on cattle & sheep farms, as a significantly higher number of non-scheme farms completed MMPs and acted upon these by implementing a greater number of specific actions. Although the change in number of non-scheme farms completing NMPs was insignificant, there was a significant positive change in non-scheme farms claiming to have carried out individual nutrient management actions between 2009 and 2016. These actions concerned activities relating to the improvement of farm business through more efficient use of resources and control of diffuse water pollution that were relatively simple to implement and involved a low capital cost, such as soil nutrient testing and calibration of the fertiliser spreader. These management actions have been encouraged through government and agricultural sector advice and guidance, most notably the Code of Good Agricultural Practice, Cross Compliance, Tried and Tested and Farming Connect. The completion of soil assessment or protection plans significantly decreased between 2009 and 2016 which can be attributed to the change in GAEC requirements under Cross Compliance. However, this did not have an adverse effect on the implementation of specific soil management actions, which showed a significant increase in uptake, particularly by DAIRY farms on grassland fields. Note that the reported marginal effects should not be interpreted directly as the change in the field areas under good management, as the survey recorded practice at a farm level and action may be taken on only part of a farm.

3. Comparative Effects of Scheme Participation

Objective*: Does Glastir scheme participation have a similar level of effect to the previous Tir Cynnal and Tir Gofal schemes on farm management?*

In order to compare the relative merit of Glastir with the previous Tir Cynnal and Tir Gofal schemes, we used the general linear modelling methodology set out in the second report (Anthony *et al*., 2016) to re-analyse the results of the first (2009) WFPS. This analysis was focussed on differences in total count of management actions carried out between scheme and non-scheme farms. There were some differences to the results previously reported (Anthony *et al*., 2012) as we relaxed constraints on the use of survey returns. For example, all farms with livestock were analysed for the scheme effect on manure management actions, and not just those with cattle. The marginal effects of the Tir Cynnal, Tir Gofal and Glastir schemes are compared. It is important to emphasise that each scheme was measured against the relevant survey year non-scheme rate, as previous analyses have demonstrated a changing rate of good practice in the non-scheme population (**Section 2**). Prior to this, we reviewed the evidence for perceived scheme effects on farm management, and actual change in nutrient use and stock numbers.

3.1 Farm Management

Farmer perception of the extent of farm management change owing to participation in previous and current agri-environment schemes, and the changes in stock number and nutrient inputs as a result of scheme participation have been assessed to compare the relative merit of the schemes.

Perception of Change

Both surveys asked respondents to score the extent to which they agreed that participation in an agri-environment scheme had '*changed my management of the farm'*. In comparison with the preceding Tir Cynnal and Tir Gofal schemes, significantly fewer respondents agreed that there had been a change in farm management under Glastir (Glastir Entry and Glastir Advanced) (*fisher exact test*, P <0.01). Overall, 61% of participants in the Tir Cynnal or Tir Gofal schemes had agreed that change had occurred, compared to 34% of participants in the Glastir scheme (**Table 3.1**) and (**Figure 3.1**). The response by the Glastir participants was unaffected by any history of participation in the previous schemes (**Figure 3.2**), supporting the conclusion that the Glastir scheme has genuinely been perceived to have resulted in less change in farm management than the preceding schemes.

Table 3.1 Percent distribution of Likert scores for agreement with a '*change in management of my farm*' on farms participating in the Glastir Scheme (second WFPS) or having participated in the Tir Cynnal or Tir Gofal schemes (first WFPS).

	Tir Cynnal or Tir Gofal		Glastir Entry or Advanced Scheme	
Level	**TG (*n* 132)**	**TC (*n* 132)**	**GA (*n* 155)**	**GE (*n* 125)**
Strongly Disagree	3	2	8	10
Disagree	18	11	12	20
Neither	23	19	39	42
Agree	48	43	23	17
Strongly Agree	8	24	17	10

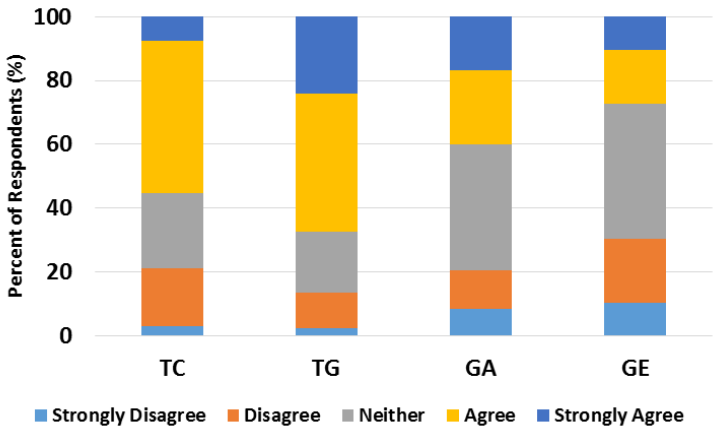

Figure 3.1 Cumulative percent of first and second Wales Farm Practice Survey respondents agreeing with the statement that participation in an agri-environment scheme had '*changed my management of the farm*', stratified by scheme: Tir Cynnal (TC); Tir Gofal (TG); Glastir Entry (GE); and Glastir Advanced (GA).

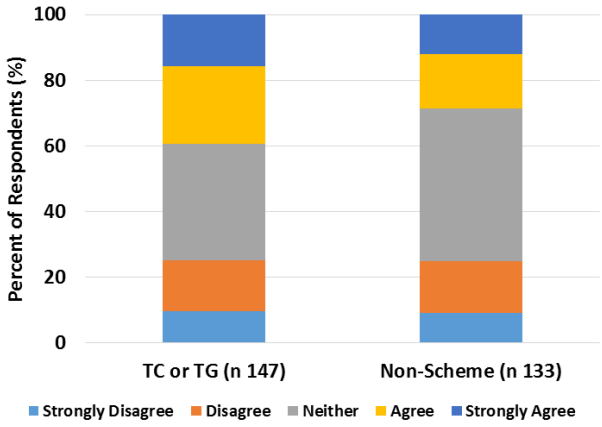

Figure 3.2 Cumulative percent of second Wales Farm Practice Survey respondents agreeing with the statement that participation in the Glastir scheme had '*changed my management of the farm*', stratified by history of participation in the preceding Tir Cynnal or Tir Gofal schemes.

Change in Stock Number

Changes in stock numbers have a direct effect on pollutant emissions, especially enteric methane emissions from ruminants that presently cannot easily be controlled by other means. In the second WFPS respondents who were participating in the Glastir scheme were asked to report any change in stock numbers that was a direct result of the current scheme agreement. Results from the previous WFPS that took place in 2009 and investigated the effects of the Tir Cynnal and Tir Gofal scheme were re-analysed using the same methodology used for the current survey (**Anthony *et al*., 2012**). The previous survey assumed that changes in stock numbers would result only from the Tir Gofal scheme and therefore the analysis was restricted to just the respondents who participated in the Tir Gofal scheme.

For farms participating in the preceding Tir Gofal scheme, there was a statistically significant net decrease of 15.4% in breeding ewe ($P < 0.01$), a decrease of 4.8% in beef suckler cow ($P < 0.05$) and a decrease of 2.4% in beef finisher cattle numbers ($P < 0.05$) (**Table 3.2**). There was no significant change in the dairy adult and dairy follower numbers. In comparison, for farms participating in the current Glastir scheme, there was a statistically significant net decrease of 3.9% in breeding ewe numbers, and a small net increase of 1.5% in beef finisher numbers ($P < 0.05$) (**Table 3.3**).

Table 3.2 Percent of survey respondents reporting an increase or decrease in the number of grazing livestock, and the net percent change in the number of livestock across all farms, attributed to participation in the Tir Gofal scheme 2009.

	Ewe (*n* 91)	**Dairy Adult (*n* 43)**	**Dairy Follower (*n* 41)**	**Beef Suckler (*n* 68)**	**Beef Finisher (*n* 83)**
Stock Decrease	33.0 (23.1 to 42.9)	9.3 (2.3 to 18.6)	2.4 (0.0 to 7.3)	13.2 (5.9 to 22.1)	10.8 (4.8 to 18.1)
Stock Increase	0.0 (0.0 to 0.0)	2.3 (0.0 to 7.0)	2.4 (0.0 to 7.3)	1.5 (0.0 to 4.4)	1.2 (0.0 to 3.6)
Net Change	-15.4 (-22.7 to -8.9)	-1.4 (-3.9 to 0.2)	-1.1 (-4.3 to 0.8)	-4.8 (-9.4 to -1.2)	-2.4 (-5.2 to -0.1)

Table 3.3 Percent of survey respondents reporting an increase or decrease in the number of grazing livestock, and the net percent change in the number of livestock across all farms, attributed to a current Glastir scheme agreement.

	Sheep (*n* 184)	**Dairy (*n* 42)**	**Beef Suckler (*n* 113)**	**Beef Finisher (*n* 24)**
Stock Decrease	19.6 (14.1 to 25.5)	4.8 (0.0 to 11.9)	9.7 (4.4 to 15.0)	0.0 (0.0 to 0.0)
Stock Increase	4.9 (2.2 to 8.2)	9.5 (2.4 to 19.0)	8.0 (3.5 to 13.3)	4.2 (0.0 to 12.5)
Net Change	-3.9 (-6.6 to -1.2)	0.8 (-1.8 to 3.3)	-1.7 (-5.2 to 2.2)	1.5 (0.0 to 5.4)

Farms participating in the current Glastir scheme were also more likely to have increased cattle numbers than those in the previous Tir Gofal scheme (**Table 3.2 and Table 3.3**), although the net effect was a reduction or no change. This supports the conclusion that the preceding Tir Gofal scheme resulted in a greater net stock reduction in comparison to the current Glastir scheme. Under the Tir Gofal scheme, participants had to adhere to the mandatory Whole Farm Section which strictly controlled stocking rates in order to reduce soil erosion. In order to meet Tir Gofal's requirements, some participants had to reduce stock density considerably (**Wales Audit Office, 2007**). In contrast, optional management agreements under the current Glastir scheme include a number of prescriptions that restrict

stocking on habitat land. Therefore, participants were only required to reduce stocking rates if they signed up to certain options, unless they were participating in the Glastir Commons, where they were required to achieve a sustainable stocking level (**Welsh Assembly Government, 2012**).

Change in Nutrient Use

It is assumed that participation in agri-environment schemes would promote and encourage net reductions in the overall use of fertiliser and chemicals through efficiency gains. In the second WFPS, respondents who were participating in the Glastir scheme were asked to report any overall change in fertiliser use that was a result of the current scheme agreement. Results from the previous WFPS that took place in 2009 and investigated the effects of the Tir Cynnal and Tir Gofal scheme were re-analysed using the same methodology used for the current survey (**Anthony *et al*., 2012**). The previous survey assumed that scheme membership would result in only a decrease in fertiliser use, and this limits the comparison.

For farms participating in the previous Tir Cynnal scheme, there was a net decrease of 11.3% in manufactured nitrogen and a decrease of 9.7% in manufactured phosphate fertiliser use on improved grassland. Similarly, a net decrease in the quantity of nitrogen (9.8%) and phosphate fertiliser (9.9%) applied to improved grassland was reported for participants in the Tir Gofal scheme (**Table 3.4**). In comparison, for farms participating in the current Glastir scheme, there was a similar and statistically significant net decrease of 8.5% in nitrogen ($P < 0.05$) and a decrease of 9.4% in phosphate fertiliser use on grassland fields ($P < 0.05$) (**Table 3.5**). Participation in all schemes was therefore associated with a similar reduction in the quantity of fertiliser used on improved grassland.

Table 3.4 Percent of survey respondents reporting a decrease in the quantity of nitrogen and phosphate fertiliser applied to improved grassland, and the net percent change in the overall rate across all farms, attributed to participation in the Tir Cynnal and Tir Gofal schemes 2009.

	Tir Cynnal		**Tir Gofal**	
	Nitrogen (*n* 90)	**Phosphate (*n* 87)**	**Nitrogen (*n* 80)**	**Phosphate (*n* 87)**
Rate Decrease	42.2 (32.2 to 52.2)	32.2 (23.0 to 42.5)	35.0 (25.0 to 46.3)	29.9 (20.7 to 40.2)
Net Change	-11.3 (-15.1 to -7.9)	-9.7 (-13.6 to -6.1)	-9.8 (-13.8 to -6.2)	-9.9 (-14.2 to -6.2)

Table 3.5 Percent of survey respondents reporting an increase or decrease in the quantity of nitrogen and phosphate fertiliser applied to improved grassland, and the net percent change in the overall rate across all farms, attributed to participation in the current Glastir scheme 2016.

	Glastir	
	Nitrogen (*n* 123)	**Phosphate (*n* 135)**
Rate Decrease	35.0 (26.8 to 43.9)	35.6 (27.4 to 43.7)
Rate Increase	4.9 (1.6 to 9.8)	4.4 (1.5 to 8.1)
Net Change	-8.5 (-12.1 to -4.8)	-9.4 (-13.0 to -5.8)

A net decrease in the quantity of nitrogen (4.7 to 6.5%) and phosphate fertiliser (3.2 to 8.7%) applied to arable land was also reported by participants in the previous Tir Cynnal and Tir Gofal schemes (**Table 3.6**). In comparison, for farms participating in the current Glastir scheme, there was a similar and statistically significant net decrease of 7.3% in the use of phosphate fertiliser ($P < 0.05$). However, there was no significant change in the quantity of nitrogen fertiliser applied to arable land (**Table 3.7**). The proportions of farmers reported a reduction in fertiliser use on arable land were similar under all schemes.

Under the previous Tir Cynnal scheme, participants were not permitted to use excessive fertiliser and lime applications and were made aware of possible over-application through the mandatory soil nutrient management plan (**Welsh Assembly Government 2005b**). Under the Tir Gofal scheme, participants could make a commitment to carrying out a range of additional work including grassland restoration. Options under this theme required participants to manage grassland without using any inorganic fertilisers and to limit application by not applying during certain times of the year (**Welsh Assembly Government 2006**). A similar situation occurs under the Glastir scheme management agreements, where a number of options restricted fertiliser rates on habitat land. The more popular of the options taken up by Glastir farmers have included “grazed permanent pasture with no or very low inputs” (No. 15 and 15b). Participants were required to apply no more than 50kg/ha nitrogen per year as inorganic fertiliser (**Welsh Assembly Government, 2013**).

Table 3.6 Percent of survey respondents reporting a decrease in the quantity of nitrogen and phosphate fertiliser applied to arable land, and the net percent change in the overall rate across all farms, attributed to participation in the Tir Cynnal and Tir Gofal schemes 2009.

	Tir Cynnal		**Tir Gofal**	
	Nitrogen (*n* 36)	**Phosphate (*n* 30)**	**Nitrogen (*n* 47)**	**Phosphate (*n* 50)**
Rate Decrease	19.4 (8.3 to 33.3)	20.0 (6.7 to 36.7)	23.4 (12.8 to 36.2)	16.0 (6.0 to 26.0)
Net Change	-6.5 (-13.5 to -1.4)	-8.7 (-17.2 to -2.2)	-4.7 (-8.1 to -2.0)	-3.2 (-6.0 to -1.0)

Table 3.7 Percent of survey respondents reporting an increase or decrease in the quantity of nitrogen and phosphate fertiliser applied to arable land, and the net percent change in the overall rate across all farms, attributed to participation in the current Glastir scheme 2016.

	Glastir	
	Nitrogen (*n* 62)	**Phosphate (*n* 64)**
Rate Decrease	19.4 (9.7 to 29.0)	21.9 (12.5 to 32.8)
Rate Increase	3.2 (0.0 to 8.1)	4.7 (0.0 to 10.9)
Net Change	-2.7 (-7.1 to 2.1)	-7.3 (-14.5 to -0.8)

3.2 Management Actions

Tables 3.8 to **3.11** summarise the total count and percent uptake of individual management actions on farms participating in Glastir in 2016, and Tir Cynnal or Tir Gofal in 2009. The uptake values can be compared with those for non-scheme farms in **Tables 2.3, 2.5, 2.7** and **2.9**.

Table 3.12 summarises the results of the general linear modelling, drawing on results tables from the second report (**Anthony *et al*., 2012**) and the re-analysis of the 2009 survey data. For each management plan, the table lists the statistically significant marginal effects over the non-scheme baselines for each survey year.

For arable and grassland soil management, the marginal effect on the total number of actions carried out were again similar for Glastir (+0.52 grassland and +1.65 arable) and for the Tir Gofal (+0.52 grassland and +1.02 arable). There was no effect of Tir Cynnal on the total number of soil management actions. There was a positive effect of both Glastir and Tir Gofal on the '*fencing off streams from livestock*', 'e*stablishing vegetated and uncultivated buffer strips*' and '*leaving stubble in field*'.

The marginal effect of Glastir scheme participation on the total number of nutrient (+0.39) and manure management (+0.51) actions carried out in 2016 was similar to that achieved by Tir Cynnal (+0.38 and +0.32) and Tir Gofal (+0.69 and +0.35) scheme participation in 2009, both relative to the non-scheme farms in the survey years. The number of individual actions for which there was a significant effect also is similar. Glastir had a statistically significant effect on 5 nutrient and manure management actions, whilst Tir Cynnal and Tir Gofal had an effect on 6 actions. However, there was only 1 action that was affected by both Glastir and the preceding schemes (**Table 3.12**). This was '*testing of soil nutrient status*'. This inconsistency, is most likely a result of the weaker scheme and lower marginal effects on nutrient and manure management actions (2 to 13%) in comparison to the three identified soil management actions (16 to 29%).

*Participants in the preceding Tir Cynnal and Tir Gofal schemes were more likely to agree that participation had '*changed my management of the farm*' than those in the Glastir scheme. There was also a greater net reduction in breeding ewe numbers under the preceding Tir Gofal scheme than the current Glastir scheme. However, the net reduction in nutrient use attributed to entry into each scheme is similar, and the marginal improvements in the total count of manure, nutrient and soil management actions carried out (in comparison to the non-scheme farms in the relevant survey year) are also of similar magnitude.*

Table 3.8 Average count of all manure management actions taken by in-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 survey, stratified by scheme type and farm type.

	Survey	Scheme	CS	DAIRY
Count of all actions (n)	2009	TC	1.8 (1.5 to 2.0) n = 84	3.2 (2.6 to 3.8) n = 45
		TG	2.0 (1.7 to 2.3) n = 83	2.7 (2.1 to 3.3) n = 44
	2016	Glastir	2.2 (1.9 to 2.5) n = 77	4.5 (3.69 to 5.5) n = 19
Increased size of slurry store (%)	2009	TC	2.4 (0.0 to 6.0)	33.3 (20.0 to 46.7)
		TG	3.6 (0.0 to 8.4)	13.6 (4.5 to 25.0)
	2016	Glastir	7.8 (2.6 to 14.3)	42.1 (21.1 to 63.2)
Bought or rented more land to spread manure (%)	2009	TC	9.5 (3.6 to 15.5)	31.1 (17.8 to 46.7)
		TG	8.4 (3.6 to 14.5)	22.7 (11.4 to 36.4)
	2016	Glastir	6.5 (1.3 to 11.7)	36.8 (15.8 to 57.9)
Exported excess manure to another holding (%)	2009	TC	2.4 (0.0 to 6.0)	15.6 (4.4 to 26.7)
		TG	2.4 (0.0 to 6.0)	4.5 (0.0 to 11.4)
	2016	Glastir	2.6 (0.0 to 6.5)	5.3 (0.0 to 15.8)
Roofed yard areas (%)	2009	TC	4.8 (1.2 to 9.5)	35.6 (22.2 to 51.1)
		TG	8.4 (2.4 to 15.7)	34.1 (20.5 to 47.7)
	2016	Glastir	11.7 (5.2 to 19.5)	47.4 (26.3 to 68.4)
Separated ‘dirty’ yard water from runoff from clean concrete and roofs (%)	2009	TC	28.6 (19.0 to 38.1)	48.9 (35.6 to 62.2)
		TG	22.9 (14.5 to 32.5)	54.5 (40.8 to 68.2)
	2016	Glastir	35.1 (24.7 to 45.5)	78.9 (57.9 to 94.7)
Reduced water usage for watering or cleaning livestock and buildings (%)	2009	TC	21.4 (13.1 to 31.0)	20.0 (8.9 to 33.3)
		TG	31.3 (21.7 to 42.2)	15.9 (6.8 to 27.3)
	2016	Glastir	20.8 (11.7 to 29.9)	57.9 (36.8 to 78.9)
Covered manure heaps (%)	2009	TC	4.8 (1.2 to 9.5)	6.7 (0.0 to 15.6)
		TG	7.2 (2.4 to 13.3)	4.5 (0.0 to 11.4)
	2016	Glastir	13.0 (6.5 to 20.8)	31.6 (10.5 to 52.6)
Moved manure heaps away from watercourse (%)	2009	TC	15.5 (8.3 to 23.8)	31.1 (17.8 to 46.7)
		TG	31.3 (20.5 to 41.0)	27.3 (13.6 to 40.9)
	2016	Glastir	37.7 (27.3 to 48.1)	21.1 (5.3 to 42.1)
Calibrated manure spreader (%)	2009	TC	4.8 (1.2 to 9.5)	20.0 (8.9 to 33.3)
		TG	10.8 (4.8 to 18.1)	13.6 (4.5 to 25.0)
	2016	Glastir	15.6 (7.8 to 23.4)	57.9 (36.8 to 78.9)
Increased proportion of manures spread during spring or growing season (%)	2009	TC	28.6 (20.2 to 38.1)	68.9 (55.6 to 82.2)
		TG	38.6 (28.9 to 49.4)	50.0 (36.4 to 63.7)
	2016	Glastir	35.1 (24.7 to 45.5)	73.7 (52.6 to 89.5)

Table 3.9 Average count of all soil nutrient management actions taken by in-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 survey, stratified by scheme type and farm type.

	Survey	Scheme	CS	DAIRY
Count of all actions (n)	2009	TC	1.5 (1.3 to 1.8) n = 66	3.0 (2.5 to 3.4) n = 44
		TG	2.1 (1.7 to 2.4) n = 59	3.0 (2.6 to 3.4) n = 38
	2016	Glastir	2.2 (1.8 to 2.5) n = 63	3.6 (2.9 to 4.1) n = 18
Calibration of the fertiliser spreader (%)	2009	TC	18.2 (9.1 to 27.3)	50.0 (36.3 to 65.9)
		TG	37.3 (25.4 to 49.2)	50.0 (34.2 to 65.8)
	2016	Glastir	42.9 (31.7 to 55.6)	83.3 (66.6 to 100)
Testing of soil nutrient status (%)	2009	TC	45.5 (33.3 to 57.6)	77.3 (63.6 to 90.9)
		TG	52.5 (39.0 to 64.4)	78.9 (65.8 to 92.1)
	2016	Glastir	57.1 (44.4 to 69.8)	83.3 (61.1 to 100)
Use a fertiliser recommendation system (%)	2009	TC	18.2 (10.6 to 27.3)	54.5 (38.6 to 68.2)
		TG	32.2 (22.0 to 44.1)	50.0 (34.2 to 65.8)
	2016	Glastir	33.3 (22.2 to 46.0)	50.0 (27.8 to 72.2)
Increased use of straight rather than compound fertiliser (%)	2009	TC	9.1 (3.0 to 16.7)	38.6 (25.0 to 52.4)
		TG	13.6 (5.1 to 23.7)	36.8 (23.6 to 52.6)
	2016	Glastir	14.3 (6.3 to 23.8)	38.9 (16.7 to 61.1)
Delayed application to avoid spreading to wet of frozen ground (%)	2009	TC	63.6 (53.0 to 74.2)	77.3 (63.6 to 88.6)
		TG	69.5 (57.6 to 81.4)	84.2 (71.1 to 94.7)
	2016	Glastir	68.3 (55.6 to 79.4)	100 (100 to 100)

Table 3.10 Average count of all soil management actions taken on grassland fields by in-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 survey, stratified by scheme type and farm type.

	Survey	Scheme	CS	DAIRY
Count of all actions (n)	2009	TC	3.2 (2.8 to 3.7) n = 81	5.2 (4.4 to 6.0) n = 45
		TG	4.3 (3.8 to 4.9) n = 83	4.1 (3.4 to 4.9) n = 44
	2016	Glastir	4.8 (4.3 to 5.2) n = 68	5.6 (4.8 to 6.4) n = 18
Delayed putting stock out to grass (%)	2009	TC	50.6 (39.5 to 60.5)	73.3 (60.0 to 86.7)
		TG	60.2 (50.6 to 71.1)	68.2 (54.5 to 81.8)
	2016	Glastir	61.8 (48.5 to 72.1)	61.1 (38.9 to 83.3)
Reduced stocking rate on fields subject to poaching (%)	2009	TC	50.6 (39.5 to 61.7)	68.9 (55.6 to 82.2)
		TG	66.3 (55.4 to 75.9)	52.3 (38.6 to 65.9)
	2016	Glastir	69.1 (58.8 to 79.4)	61.1 (38.9 to 83.3)
Reduced length of grazing season or day (%)	2009	TC	34.6 (23.5 to 44.4)	60.0 (46.7 to 73.3)
		TG	50.6 (39.8 to 61.4)	45.5 (31.8 to 59.1)
	2016	Glastir	30.9 (20.6 to 42.6)	55.6 (33.3 to 77.8)
Improved drainage on poached fields (%)	2009	TC	13.6 (6.2 to 22.2)	31.1 (17.8 to 46.7)
		TG	18.1 (10.8 to 26.5)	22.7 (11.4 to 36.4)
	2016	Glastir	38.2 (26.5 to 50.0)	33.3 (11.1 to 55.6)
Remove compaction by re-seeding or soil loosening (%)	2009	TC	28.4 (19.8 to 38.3)	64.4 (51.1 to 77.9)
		TG	33.7 (24.1 to 44.6)	36.4 (22.7 to 50.0)
	2016	Glastir	51.5 (39.7 to 63.2)	94.4 (83.3 to 100)
Fenced off streams from livestock (%)	2009	TC	13.6 (6.2 to 21.0)	42.2 (28.9 to 57.8)
		TG	51.8 (41.0 to 62.7)	52.3 (38.6 to 68.2)
	2016	Glastir	52.9 (41.2 to 64.7)	72.2 (50.0 to 88.9)
Provided in-field watering points (%)	2009	TC	39.5 (28.4 to 50.6)	68.9 (55.6 to 82.2)
		TG	48.2 (38.6 to 59.0)	52.3 (38.6 to 68.2)
	2016	Glastir	55.9 (44.1 to 67.6)	88.9 (72.2 to 100)
Re-sited or regularly rotated feeding sites (%)	2009	TC	39.5 (28.4 to 49.4)	53.3 (40.0 to 66.7)
		TG	62.7 (51.8 to 72.3)	38.6 (25.0 to 52.3)
	2016	Glastir	77.9 (69.1 to 86.8)	77.8 (55.6 to 94.4)
No longer out-winter cattle (%)	2009	TC	53.1 (43.2 to 64.2)	62.2 (48.9 to 77.8)
		TG	42.2 (31.3 to 53.0)	45.5 (31.8 to 61.4)
	2016	Glastir	38.2 (26.5 to 50.0)	16.7 (0.0 to 33.3)

Table 3.11 Average count of all soil management actions taken on arable fields by in-scheme farmers and the percent of farms taking specific action in the 2009 and 2016 survey, stratified by scheme type and farm type.

	Survey	Scheme	CS	DAIRY
Count of all actions (n)	2009	TC	3.1 (2.4 to 4.0) n = 20	4.8 (3.3 to 6.2) n = 18
		TG	5.7 (4.8 to 6.7) n = 38	3.8 (2.9 to 4.8) n = 28
	2016	Glastir	5.0 (3.8 to 6.1) n = 29	6.1 (4.6 to 7.8) n = 11
Established winter cover by early drilling (%)	2009	TC	60.0 (40.0 to 80.0)	33.3 (11.1 to 55.6)
		TG	44.7 (28.9 to 60.5)	39.3 (21.4 to 57.1)
	2016	Glastir	44.8 (27.6 to 62.1)	27.3 (0.0 to 54.5)
Leave stubble in field (%)	2009	TC	10.0 (0.0 to 25.0)	38.9 (16.7 to 61.1)
		TG	57.9 (42.1 to 73.7)	28.6 (10.7 to 46.4)
	2016	Glastir	48.3 (31.0 to 65.5)	90.9 (72.7 to 100)
Established winter cover by sowing cover crop (%)	2009	TC	25.0 (5.0 to 45.0)	44.4 (22.2 to 66.7)
		TG	60.5 (44.7 to 73.7)	35.7 (17.9 to 53.6)
	2016	Glastir	51.7 (34.5 to 69.0)	45.5 (18.2 to 72.7)
Delayed field operations to avoid working on wet soil (%)	2009	TC	80.0 (65.0 to 95.0)	83.3 (66.7 to 100)
		TG	86.8 (76.3 to 97.4)	82.1 (67.9 to 96.4)
	2016	Glastir	69.0 (51.7 to 86.2)	81.8 (54.5 to 100)
Used minimal cultivation techniques (%)	2009	TC	25.0 (5.0 to 45.0)	33.3 (11.1 to 55.6)
		TG	44.7 (28.9 to 60.5)	32.1 (14.3 to 50.0)
	2016	Glastir	48.3 (31.0 to 69.0)	45.5 (18.2 to 72.7)
Rough ploughing to remove harvest compaction (%)	2009	TC	20.0 (5.0 to 40.0)	16.7 (0.0 to 33.4)
		TG	31.6 (18.4 to 44.8)	17.9 (7.1 to 32.1)
	2016	Glastir	41.4 (24.1 to 58.6)	45.5 (18.2 to 72.7)
Loosened or disrupted compacted tramlines (%)	2009	TC	20.0 (5.0 to 40.0)	22.2 (5.6 to 44.4)
		TG	13.2 (2.6 to 23.7)	21.4 (7.1 to 39.3)
	2016	Glastir	17.2 (3.4 to 31.0)	27.3 (0.0 to 54.5)
Delayed tramline establishment (%)	2009	TC	5.0 (0.0 to 15.0)	11.1 (0.0 to 27.8)
		TG	7.9 (0.0 to 18.4)	7.1 (0.0 to 17.9)
	2016	Glastir	3.4 (0.0 to 10.3)	18.2 (0.0 to 45.5)
Delayed cultivation for spring sown crops until the spring (%)	2009	TC	25.0 (10.0 to 45.0)	66.7 (44.4 to 88.9)
		TG	65.8 (50.0 to 81.6)	32.1 (14.3 to 50.0)
	2016	Glastir	58.6 (41.4 to 75.9)	90.9 (72.7 to 100)
Left autumn seed beds rough (%)	2009	TC	10.0 (0.0 to 25.0)	44.4 (22.2 to 66.7)
		TG	34.2 (18.4 to 50.0)	35.7 (17.9 to 53.6)
	2016	Glastir	17.2 (3.4 to 31.0)	45.5 (18.2 to 72.7)
Cultivating across slope (%)	2009	TC	10.0 (0.0 to 25.0)	33.3 (11.1 to 55.6)
		TG	31.6 (15.8 to 47.4)	10.7 (0.0 to 21.4)
	2016	Glastir	31.0 (13.8 to 48.3)	18.2 (0.0 to 45.5)
Established vegetated and uncultivated buffer strip (%)	2009	TC	5.0 (0.0 to 15.0)	27.8 (11.1 to 50.0)
		TG	47.4 (31.6 to 63.2)	21.4 (7.1 to 35.7)
	2016	Glastir	37.9 (20.7 to 55.2)	45.5 (18.2 to 72.7)
Convert field corners to grass or bird cover (%)	2009	TC	15.0 (0.0 to 30.1)	22.2 (5.6 to 44.4)
		TG	47.4 (31.6 to 63.2)	14.3 (3.6 to 28.6)
	2016	Glastir	27.6 (13.8 to 44.8)	27.3 (0.0 to 54.5)

Table 3.12 Statistically significant marginal effects of scheme participation on the uptake of individual management actions associated with nutrient, manure and soil management plans. Results are listed for the effects of the Tir Cynnal and Tir Gofal schemes in 2009, and for the effects of the Glastir scheme, relative to the non-scheme baseline for each year.

Plan	Management Action	Tir Cynnal		Tir Gofal		Glastir	
		P	Margin	P	Margin	P	Margin
Soil (Grass)	***Count of Actions (n)***			***0.01***	***0.52***	***0.01***	***0.52***
	Delayed putting stock out to grass (%)						
	Reduced stocking rate on field subject to poaching (%)	0.04	0.1	0.01	0.15		
	Reduced length of grazing season or day (%)			0.04	0.1		
	Improved drainage on poached fields (%)						
	Remove compaction by re-seeding or soil loosening (%)						
	Fenced off streams form livestock (%)			0.001	0.27	*0.01	*0.29
	Provided in-field watering points (%)						
	Re-sited or regularly rotated feeding sites (%)					*0.01	*0.16
	No longer out-winter cattle (%)	0.01	0.12				
Soil (Arable)	***Count of Actions (n)***			***0.001***	***1.02***	****0.01***	****1.65***
	Established winter cover by early drilling (%)						
	Leave stubble in field (%)			0.03	0.16	*0.01	*0.25
	Established winter cover by sowing cover crop (%)			0.04	0.15		
	Delayed field operations to avoid working on wet soil (%)						
	Used minimal cultivation techniques (%)						
	Rough ploughing to remove harvest compaction (%)						
	Loosened or disrupted compacted tramlines (%)						
	Delayed tramline establishment (%)						
	Delayed cultivation for spring sown crops until the spring (%)						
	Left autumn seed beds rough (%)						
	Cultivating across slope (%)						
	Established vegetated and uncultivated buffer strip (%)			0.001	0.23	0.01	0.26
	Convert field corners to grass or bird cover (%)			0.04	0.14		

*Glastir Advanced effect only

Table 3.12. *cont.* Statistically significant marginal effects of scheme participation on the uptake of individual management actions associated with nutrient, manure and soil management plans. Results are listed for the effects of the Tir Cynnal and Tir Gofal schemes in 2009, and for the effects of the Glastir scheme, relative to the non-scheme baseline for each year.

Plan	Management Action	Tir Cynnal		Tir Gofal		Glastir	
		P	**Margin**	**P**	**Margin**	**P**	**Margin**
Nutrient	***Count of Actions (n)***	***0.03***	***0.38***	***0.001***	***0.69***	***0.02***	***0.39***
	Calibration of the fertiliser spreader (%)					0.02	0.13
	Testing of soil nutrient status (%)	0.001	0.21	0.001	0.26	0.02	0.13
	Use a fertiliser recommendation system (%)			0.03	0.12		
	Increased use of straight rather than compound fertiliser (%)	0.05	0.09	0.02	0.11		
	Delay application to avoid spreading to wet or frozen ground (%)					0.01	0.13
Manure	***Count of Actions (n)***	***0.03***	***0.32***	***0.02***	***0.35***	***0.01***	***0.51***
	Increased size of slurry store (%)					0.01	0.07
	Bought or rented more land to spread manure (%)						
	Exported excess manure to another holding (%)	0.03	0.03				
	Roofed yard areas (%)						
	Separated 'dirty' yard water from runoff from clean concrete and roofs (%)						
	Reduced water usage for watering or cleaning livestock and buildings (%)						
	Covered manure heaps (%)					0.01	0.07
	Moved manure heaps away from watercourse (%)			0.01	0.11		
	Calibrated manure spreader (%)					0.03	0.08
	Increased proportion of manures spread during spring or growing season (%)	0.02	0.12	0.02	0.13		

4. Legacy Effects of Tir Cynnal and Tir Gofal Schemes

Objective*: Is there any evidence that there is a legacy of improved practice from the Tir Cynnal and Tir Gofal schemes?*

The previous report on the main results of the 2016 survey (**Anthony *et al*., 2016**) documented an analysis of whether there was a positive effect of a history of participation in the preceding Tir Cynnal or Tir Gofal schemes on the level of uptake of individual management actions in 2016, relative to the level of uptake on non-scheme farms also in 2016. That analysis found effects of participation in the preceding schemes on the level of uptake of four nutrient and manure management actions. The preceding **Section 3** found effects of participation in either the Tir Cynnal or Tir Gofal scheme, relative to the level of uptake on non-scheme farms in 2009, for a total of 14 nutrient, manure and soil management actions. The difference may in part by explained by changing statistical power of the analyses. However, given the evidence for an improvement in the level of uptake of management actions on non-scheme farms between 2009 and 2016 (**Section 2**), it was hypothesised that the previous analysis of the 2016 survey may underestimate any legacy of the preceding schemes, as non-scheme farms may have recently advanced to a level comparable to that previously achieved under scheme in 2009, reducing the current difference in uptake between non-scheme and previously in-scheme farm populations.

To assess this possibility, we carried out further analyses in which we tested for a difference in the level of uptake between the non-scheme farms in 2009 and the previously in-scheme farm populations in 2016. A significant Fisher-Exact test would indicate that the marginal effect of Tir Cynnal or Tir Gofal observed in 2009 had persisted through to 2016.

Tables 4.1 to 4.4 summarise the level of uptake of individual actions on farms surveyed in 2016 that had previously participated in Tir Cynnal or Tir Gofal, but had not entered the Glastir scheme. They can be compared with the uptake on non-scheme farms in 2009 (**Tables 2.3, 2.5 and 2.7**). **Tables 4.5 to 4.8** summarise the results of the Fisher-Exact test analyses for actions associated with nutrient, manure and soil management plans. Overall, the majority of calculated odds-ratios were less than 1 for the soil management actions on arable land (5 of 6) and on grassland (7 of 7), for nutrient management actions (3 of 4) and for manure management actions (3 of 4), where an effect of scheme in 2009 had been previously established (**Tables 4.5 to 4.8**). These results indicate that the marginal uptake over non-scheme farms established in 2009 persisted through to 2016. However, the statistical test was only significant for 8 of the management actions, partly as a result of reduced margins in some cases, but mainly because of a much reduced number of respondents in 2016 that impacted on the power of the analysis.

There was a persistent effect of previous participation in the Tir Cynnal and Tir Gofal schemes in 2009 on the uptake of selected management actions surveyed on farms that had not entered Glastir in 2016. This result depended on a comparison of the 2009 and 2016 survey results, as the recorded effect of previous scheme participation in 2016 was confounded by an increase in the uptake of management actions on non-scheme farms between 2009 and 2016.

Table 4.1 Average count of all manure management actions taken by post-scheme farmers and the percent of farms taking specific action in the 2016 survey, stratified by scheme type and farm type.

	Scheme	CS	DAIRY
Count of all actions (n)	**In-scheme: TC**	1.1 (0.7 to 1.5) n = 43	3.1 (2.3 to 4) n = 14
	In-scheme: TG	1.8 (1.4 to 2.2) n = 55	3.1 (2.3 to 4.1) n = 19
Increased size of slurry store	**In-scheme: TC**	0.0 (0.0 to 0.0)	21.4 (0.0 to 42.9)
	In-scheme: TG	3.6 (0.0 to 9.1)	26.3 (10.5 to 47.4)
Bought or rented more land to spread manure	**In-scheme: TC**	4.7 (0.0 to 11.6)	28.6 (7.1 to 50.0)
	In-scheme: TG	7.3 (1.8 to 14.5)	36.8 (15.8 to 57.9)
Exported excess manure to another holding	**In-scheme: TC**	2.3 (0.0 to 7.0)	21.4 (0.0 to 42.9)
	In-scheme: TG	0.0 (0.0 to 0.0)	21.1 (5.3 to 42.1)
Roofed yard areas	**In-scheme: TC**	11.6 (2.3 to 23.3)	35.7 (7.1 to 64.3)
	In-scheme: TG	12.7 (5.5 to 21.8)	31.6 (10.5 to 52.6)
Separated ‘dirty’ yard water from runoff from clean concrete and roofs	**In-scheme: TC**	14.0 (4.7 to 25.6)	71.4 (49.8 to 92.9)
	In-scheme: TG	38.2 (25.5 to 50.9)	42.1 (21.1 to 63.2)
Reduced water usage for watering or cleaning livestock and buildings	**In-scheme: TC**	7.0 (0.0 to 16.3)	21.4 (0.0 to 42.9)
	In-scheme: TG	21.8 (12.7 to 32.7)	21.1 (5.3 to 36.8)
Covered manure heaps	**In-scheme: TC**	2.3 (0.0 to 7.0)	7.1 (0.0 to 21.4)
	In-scheme: TG	12.7 (3.6 to 21.8)	5.3 (0.0 to 15.8)
Moved manure heaps away from watercourse	**In-scheme: TC**	25.6 (14 to 39.5)	28.6 (7.1 to 50.0)
	In-scheme: TG	30.9 (20 to 43.6)	26.3 (10.4 to 47.4)
Calibrated manure spreader	**In-scheme: TC**	9.3 (2.3 to 18.6)	14.3 (0.0 to 35.7)
	In-scheme: TG	18.2 (9.1 to 29.1)	26.3 (10.5 to 47.4)
Increased proportion of manures spread during spring or growing season	**In-scheme: TC**	30.2 (18.5 to 44.2)	64.3 (42.9 to 85.7)
	In-scheme: TG	34.5 (21.8 to 47.3)	73.7 (52.6 to 89.6)

Table 4.2 Average count of all nutrient management actions taken by post-scheme farmers and the percent of farms taking specific action in the 2016 survey, stratified by scheme type and farm type.

	Scheme	CS	DAIRY
Count of all actions (n)	**In-scheme: TC**	2.5 (2.1 to 3) n = 39	3.4 (3 to 3.8) n = 19
	In-scheme: TG	2.2 (1.6 to 2.8) n = 28	2.8 (1.8 to 3.7) n = 12
Calibration of fertiliser spreader	**In-scheme: TC**	43.6 (28.2 to 59.0)	68.4 (47.4 to 89.5)
	In-scheme: TG	46.4 (28.6 to 64.3)	66.7 (41.7 to 91.7)
Testing of soil nutrient status	**In-scheme: TC**	64.1 (48.7 to 79.5)	94.7 (84.2 to 100)
	In-scheme: TG	57.1 (39.3 to 75.0)	66.7 (41.7 to 91.7)
Use a fertiliser recommendation system	**In-scheme: TC**	48.7 (33.3 to 66.7)	63.2 (42.1 to 84.2)
	In-scheme: TG	42.9 (25.0 to 60.7)	50.0 (25.0 to 75.0)
Increased use of straight rather than compound fertiliser	**In-scheme: TC**	23.1 (12.7 to 35.9)	47.4 (26.3 to 68.4)
	In-scheme: TG	21.4 (7.1 to 39.3)	16.7 (0.0 to 41.7)
Delayed application to avoid spreading to wet of frozen ground	**In-scheme: TC**	71.8 (56.4 to 84.6)	68.4 (47.4 to 89.5)
	In-scheme: TG	50.0 (32.1 to 67.9)	75.0 (50.0 to 100)

*,**,*** Statistically significant change detected

Table 4.3 Average count of all soil management actions taken on grassland fields by post-scheme farmers and the percent of farms taking specific action in the 2016 survey, stratified by scheme type and farm type.

	Scheme	CS	DAIRY
Count of all actions (n)	**In-scheme: TC**	4.2 (3.6 to 4.8) n = 47	4.4 (3.4 to 5.4) n = 16
	In-scheme: TG	4.3 (3.5 to 5.3) n = 34	4.5 (3.4 to 5.6) n = 13
Delayed putting stock out to grass	**In-scheme: TC**	59.6 (46.8 to 72.3)	43.8 (18.8 to 68.8)
	In-scheme: TG	44.1 (29.4 to 61.8)	53.8 (23.1 to 84.6)
Reduced stocking rate on fields subject to poaching	**In-scheme: TC**	59.6 (44.7 to 72.3)	43.8 (18.8 to 68.8)
	In-scheme: TG	55.9 (38.2 to 70.6)	84.6 (61.5 to 100)
Reduced length of grazing season or day	**In-scheme: TC**	25.5 (12.8 to 38.3)	18.8 (0.0 to 37.5)
	In-scheme: TG	44.1 (29.3 to 61.8)	53.8 (30.8 to 84.6)
Improved drainage on poached fields	**In-scheme: TC**	36.2 (23.4 to 51.1)	31.2 (12.5 to 56.2)
	In-scheme: TG	50.0 (32.4 to 64.7)	15.4 (0.0 to 38.5)
Remove compaction by re-seeding or soil loosening	**In-scheme: TC**	59.6 (44.7 to 72.3)	75.0 (50.0 to 93.8)
	In-scheme: TG	61.8 (44.1 to 76.5)	69.2 (46.2 to 92.3)
Fenced off streams from livestock	**In-scheme: TC**	34.0 (21.3 to 46.8)	56.2 (31.2 to 81.2)
	In-scheme: TG	44.1 (29.4 to 61.8)	38.5 (15.4 to 69.2)
Provided in-field watering points	**In-scheme: TC**	63.8 (51.1 to 76.7)	87.5 (68.8 to 100)
	In-scheme: TG	58.8 (41.2 to 73.5)	84.6 (61.5 to 100)
Re-sited or regularly rotated feeding sites	**In-scheme: TC**	61.7 (48.9 to 74.5)	43.8 (18.8 to 68.8)
	In-scheme: TG	61.8 (44.1 to 79.4)	38.5 (15.4 to 69.2)
No longer out-winter cattle	**In-scheme: TC**	23.4 (12.8 to 36.2)	43.8 (24.8 to 68.8)
	In-scheme: TG	11.8 (2.9 to 23.5)	15.4 (0.0 to 38.5)

Table 4.4 Average count of all nutrient management actions taken on arable fields by post-scheme farmers and the percent of farms taking specific action in the 2016 survey, stratified by scheme type and farm type.

	Scheme	CS	DAIRY
Count of all actions (n)	**In-scheme: TC**	5.2 (3.8 to 6.6) n = 9	4.6 (2.7 to 6.6) n = 10
	In-scheme: TG	5.0 (2.6 to 8.0) n = 7	6.0 (5.3 to 6.8) n = 4
Established winter cover by early drilling	**In-scheme: TC**	33.3 (11.1 to 66.7)	30.0 (10.0 to 60.0)
	In-scheme: TG	28.6 (0.0 to 57.1)	50.0 (0.0 to 100)
Leave stubble in field	**In-scheme: TC**	55.6 (22.2 to 88.9)	40.0 (10.0 to 70.0)
	In-scheme: TG	14.3 (0.0 to 42.9)	25.0 (0.0 to 75.0)
Established winter cover by sowing cover crop	**In-scheme: TC**	44.4 (11.1 to 77.8)	20.0 (0.0 to 50.0)
	In-scheme: TG	57.1 (28.6 to 85.7)	75.0 (25.0 to 100)
Delayed field operations to avoid working on wet soil	**In-scheme: TC**	77.8 (44.4 to 100)	70.0 (40.0 to 100)
	In-scheme: TG	71.4 (42.9 to 100)	100 (100 to 100)
Used minimal cultivation techniques	**In-scheme: TC**	66.7 (33.3 to 100)	30.0 (0.0 to 60.0)
	In-scheme: TG	57.1 (14.3 to 85.7)	75.0 (25.0 to 100)
Rough ploughing to remove harvest compaction	**In-scheme: TC**	22.2 (0.0 to 55.6)	40.0 (10.0 to 70.0)
	In-scheme: TG	14.3 (0.0 to 42.9)	25.0 (0.0 to 75.0)
Loosened or disrupted compacted tramlines	**In-scheme: TC**	22.2 (0.0 to 55.6)	40.0 (10.0 to 70.0)
	In-scheme: TG	28.6 (0.0 to 57.1)	0.0 (0.0 to 0.0)
Delayed tramline establishment	**In-scheme: TC**	0.0 (0.0 to 0.0)	20.0 (0.0 to 50.0)
	In-scheme: TG	28.6 (0.0 to 57.1)	25.0 (0.0 to 75.0)
Delayed cultivation for spring sown crops until the spring	**In-scheme: TC**	66.7 (33.3 to 100)	60.0 (30.0 to 90.0)
	In-scheme: TG	71.4 (42.9 to 100)	50.0 (0.0 to 100)
Left autumn seed beds rough	**In-scheme: TC**	22.2 (0.0 to 44.4)	20.0 (0.0 to 50.0)
	In-scheme: TG	28.6 (0.0 to 71.4)	25.0 (0.0 to 75.0)
Cultivating across slope	**In-scheme: TC**	55.6 (22.2 to 88.9)	30.0 (0.0 to 60.0)
	In-scheme: TG	28.6 (0.0 to 57.1)	50.0 (0.0 to 100)
Established vegetated and uncultivated buffer strip	**In-scheme: TC**	0.0 (0.0 to 0.0)	20.0 (0.0 to 50.0)
	In-scheme: TG	28.6 (0.0 to 71.4)	50.0 (0.0 to 100.0)
Convert field corners to grass or bird cover	**In-scheme: TC**	44.4 (11.1 to 77.8)	20.0 (0.0 to 50.0)
	In-scheme: TG	42.9 (14.3 to 71.4)	50.0 (0.0 to 100.0)

Table 4.5 Results of Fisher-Exact tests comparing percent uptake of manure management actions for on farms were in-scheme in 2009, and were non-scheme in 2016 but had previously participated in Tir Cynnal or Tir Gofal.

			*Percent Uptake (%)			Fisher-Test Probability (Odds Ratio)	
Farm Type	**Management Action**	**Year**	**Tir Cynnal**	**Tir Gofal**	**Non-Scheme**	**TC vs NS**	**TG vs NS**
Cattle and Sheep	Separated dirty yard water from runoff from clean concrete and roofs	2009	29		16	1.000 (1.13)	
		2016	14		31		
	Reduced water usage for watering or cleaning livestock and buildings	2009	21	31	10	0.771 (1.44)	0.033 (0.39)
		2016	7	22	20		
	Moved manure heaps away from watercourse	2009		31	14		0.007 (0.36)
		2016		31	27		
	Increased proportion of manures spread during spring or growing season	2009		39	20		0.027 (0.46)
		2016		35	31		
Dairy	Increased proportion of manures spread during spring or growing season	2009	69		52	0.773 (0.79)	
		2016	64		37		

*Listed uptake in 2016 for scheme farms is for respondents with a history of participation in Tir Cynnal or Tir Gofal.

Table 4.6 Results of Fisher-Exact tests comparing percent uptake of nutrient management actions for on farms were in-scheme in 2009, and were non-scheme in 2016 but had previously participated in Tir Cynnal or Tir Gofal.

			*Percent Uptake (%)			Fisher-Test Probability (Odds Ratio)	
Farm Type	**Management Action**	**Year**	**Tir Cynnal**	**Tir Gofal**	**Non-Scheme**	**TC vs NS**	**TG vs NS**
Cattle and Sheep	Calibration of fertiliser spreader	2009		37	26		0.039 (0.40)
		2016		46	39		
	Testing of soil nutrient status	2009	46	53	26	0.000 (0.20)	0.003 (0.26)
		2016	64	57	49		
	Use a fertiliser recommendation system	2009		32	14		0.001 (0.21)
		2016		43	33		
Dairy	Increased use of straight rather than compound fertiliser	2009	39	37	19	0.015 (0.26)	1 .000 (1.16)
		2016	47	17	38		

Table 4.7 Results of Fisher-Exact tests comparing percent uptake of soil management actions undertaken on grassland fields for on farms were in-scheme in 2009, and were non-scheme in 2016 but had previously participated in Tir Cynnal or Tir Gofal.

			*Percent Uptake (%)			Fisher-Test Probability (Odds Ratio)	
Farm Type	**Management Action**	**Year**	**Tir Cynnal**	**Tir Gofal**	**Non-Scheme**	**TC vs NS**	**TG vs NS**
Cattle and Sheep	Reduced stocking rate on fields subject to poaching	2009		66	44		0.26 (0.63)
		2016		56	62		
	Reduced length of grazing season or day	2009		51	35		0.33 (0.67)
		2016		44	45		
	Fenced off streams from livestock	2009		52	23		0.018 (0.38)
		2016		44	28		
	Re-sited or regularly rotated feeding sites	2009		63	48		0.189 (0.57)
		2016		62	70		
	No longer out-winter cattle	2009	53		35	0.161 (1.76)	
		2016	23		35		
Dairy	Reduced stocking rate on fields subject to poaching	2009	69		50	0.787 (1.28)	
		2016	44		73		
	Remove compaction by re-seeding or soil loosening	2009	64		38	0.011 (0.20)	
		2016	75		82		
	Fenced off streams from livestock	2009		52	29	0.529 (0.67)	
		2016		39	58		
	Provided in-field watering points	2009	69		41	0.001 (0.10)	
		2016	88		73		

Table 4.8 Results of Fisher-Exact tests comparing percent uptake of soil management actions undertaken on arable fields for on farms were in-scheme in 2009, and were non-scheme in 2016 but had previously participated in Tir Cynnal or Tir Gofal.

			*Percent Uptake (%)			Fisher-Test Probability (Odds Ratio)	
Farm Type	**Management Action**	**Year**	**Tir Cynnal**	**Tir Gofal**	**Non-Scheme**	**TC vs NS**	**TG vs NS**
Cattle and Sheep	Leave stubble in field	2009		58	26		1.000 (2.04)
		2016		14	39		
	Established winter cover by sowing cover crop	2009		61	31		0.216 (0.34)
		2016		57	45		
	Delayed cultivation for spring sown crops until the spring	2009		66	39		0.213 (0.26)
		2016		71	45		
	Left autumn seed beds rough	2009		34	18		0.609 (0.56)
		2016		29	13		
	Established vegetated and uncultivated buffer strip	2009		47	10		0.221 (0.30)
		2016		29	7		
	Convert field corners to grass or bird cover	2009		47	21		0.333 (0.35)
		2016		43	16		

5. Management Plans as Indicators

Objective*: Is there any evidence that completion of farm management plans can be used to identify farms with improved practice, either causally or by association?*

This analysis established whether the rate of uptake of individual management actions was associated with the completion of management plans. The analysis involved all respondents of the 2009 and 2016 surveys, except those in 2016 that had previously been in Tir Cynnal or Tir Gofal. This enabled direct comparability with the analysis carried out in Section 3 and simplified interpretation. Both the 2009 and 2016 surveys established the percentage of non-scheme and in-scheme farms having completed management plans as a general indication of awareness and risk assessment, and collected information on specific management actions carried out by farmers to establish the rate of which good practice was being implemented. The analysis related uptake of actions to completion of a plan in place of scheme participation. Survey questions were analysed for all farms regardless of their livestock composition and stratified by farm type. Further work that limits specific actions to farms based on composition of livestock may therefore provide slightly different results.

5.1 Manure Management

Completion of a manure management plan (MMP) was associated with a statistically significant increase in the total number of manure management actions undertaken by CS and DAIRY farms (*generalised linear model*, P <0.01). In general, CS farms completing a MMP carried out 0.6 more total management actions (**Table 5.1**). The increase in the total number of actions on DAIRY farms completing a MMP (1.15) was nearly twice that of CS farms (**Table 5.2**). The completion of a MMP is significantly associated with an increased proportion of CS farms claiming to have carried out a number of individual management actions (**Figure 5.1**), with the exception of '*exported excess manure to another holding*' (*generalised linear model*, P >0.05).The calculated marginal effects ranged from 3.7% for '*increased size of slurry store*' (*generalised linear model*, P 0.02) to 19.7% for '*increased proportion of manures spread during spring or growing season*' (*generalised linear model*, P<0.01) (**Table 5.1**). The greater marginal effects were associated with specific actions most applicable to CS farm systems, for example, '*increased proportion of manures spread during spring or growing season*' and '*moved manure heaps away from watercourse*'. The effect of MMP on the uptake of individual actions is consistent in both survey years with the exception of '*bought or rented more land to spread manure*', where the effect of having a MMP in place was only observed in 2009. The calculated marginal effect was 7.2% (*generalised linear model*, P <0.01). In contrast, completion of a MMP was only significantly associated with two individual actions on DAIRY farms (*generalised linear model*, P <0.01) (**Figure 5.1**). These actions were '*increased the size of slurry store*' and '*increased proportion of manures spread during spring or growing season*', both of which are applicable to DAIRY farm systems that manage the majority of manure as slurry. The calculated marginal effects were 21.7 and 25.1% respectively (**Table 5.2**). The completion of MMP therefore appears to be a diagnostic for CS farms to imply certain actions, whereas it is less useful for DAIRY farms. The fewer DAIRY farms in the analysis compared to CS farms means it is harder to detect effects of MMP on individual actions, but the net effect overall on the total number of actions is more robust.

Table 5.1 Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.370	0.052	7.133	0.000
		Plan	0.346	0.067	5.137	0.000
		AIC:	1591.125			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.598	0.115	5.178	0.000
Binomial Model Coefficients and Marginal Effects						
Increased the size of your slurry store		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-4.147	0.504	-8.229	0.000
		Plan	1.257	0.574	2.190	0.029
		AIC:	154.934			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.037	0.016	2.358	0.018
Bought or rented more land to spread manure		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-3.407	0.415	-8.21	0
		Year_16	0.603	0.661	0.912	0.362
		Plan	1.446	0.482	3	0.003
		Year_16:Plan	-2.235	0.916	-2.439	0.015
		AIC:	234.449			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.032	0.037	0.842	0.4
		Plan	0.072	0.024	2.968	0.003
		Year_16:Plan	-0.07	0.02	-3.544	0
Roofed yard areas		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-3.316	0.339	-9.773	0.000
		Plan	1.396	0.386	3.618	0.000
		AIC:	285.356			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.093	0.023	3.955	0.000
Separated 'dirty' yard water from runoff from clean concrete and roofs		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.701	0.180	-9.477	0.000
		Year_16	0.497	0.211	2.355	0.019
		Plan	0.726	0.213	3.406	0.001
		AIC:	572.259			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.094	0.041	2.290	0.022
		Plan	0.131	0.038	3.490	0.000

Table 5.1 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Reduced water usage for watering or cleaning livestock and buildings		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.721	0.174	-9.898	0.000
		Plan	0.487	0.227	2.143	0.032
		AIC:	506.841			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.074	0.034	2.169	0.030
Covered manure heaps		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-3.438	0.359	-9.572	0.000
		Plan	1.032	0.423	2.442	0.015
		AIC:	227.059			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.052	0.020	2.571	0.010
Moved manure heaps away from watercourse		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.869	0.189	-9.892	0.000
		Year_16	0.570	0.216	2.640	0.008
		Plan	0.788	0.221	3.572	0.000
		AIC:	548.330			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.102	0.040	2.552	0.011
		Plan	0.134	0.037	3.674	0.000
Calibrated manure spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.414	0.197	-12.238	0.000
		Year_16	0.666	0.287	2.322	0.020
		AIC:	350.439			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.066	0.030	2.190	0.029
Increased proportion of manures spread during spring or growing season		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.471	0.16	-9.191	0
		Plan	0.996	0.204	4.889	0
		AIC:	605.663			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.197	0.038	5.113	0

Table 5.2 Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken by in-scheme DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Total Count of Actions		(Intercept)	0.615	0.137	4.483	0.000
		Year_16	0.213	0.084	2.550	0.011
		Plan	0.465	0.142	3.276	0.001
		AIC:	931.367			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.663	0.274	2.419	0.016
		Plan	1.153	0.293	3.940	0.000
Binomial Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Increased the size of your slurry store		(Intercept)	-3.296	1.018	-3.238	0.001
		Plan	2.210	1.030	2.145	0.032
		AIC:	245.402			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.217	0.046	4.680	0.000
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Separated 'dirty' yard water from runoff from clean concrete and roofs		(Intercept)	0.079	0.150	0.526	0.599
		Year_16	0.694	0.322	2.154	0.031
		AIC:	320.194			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.164	0.072	2.280	0.023
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Reduced water usage for watering or cleaning livestock and buildings		(Intercept)	-1.076	0.173	-6.234	0.000
		Year_16	0.829	0.318	2.609	0.009
		AIC:	282.855			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.184	0.073	2.511	0.012
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Covered manure heaps		(Intercept)	-2.815	0.326	-8.648	0.000
		Year_16	1.141	0.488	2.340	0.019
		AIC:	130.618			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.101	0.051	1.976	0.048

Table 5.2 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken by in-scheme DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Moved manure heaps away from watercourse		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.047	0.171	-6.106	0.000
		Year_16	0.728	0.318	2.287	0.022
		AIC:	284.412			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.161	0.073	2.201	0.028
Calibrated manure spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.550	0.198	-7.836	0.000
		Year_16	1.303	0.332	3.922	0.000
		AIC:	246.394			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.263	0.072	3.676	0.000
Increased proportion of manures spread during spring or growing season		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.747	0.405	-1.847	0.065
		Plan	1.041	0.428	2.429	0.015
		AIC:	320.357			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.251	0.095	2.653	0.008

5.2 Nutrient Management

Statistical modelling established that the total number of nutrient management actions was significantly higher on farms completing a nutrient management plan (NMP) in comparison to farms without a NMP in place. This was true of both CS and DAIRY farms that shared similar marginal effects (*generalised linear model*, P<0.01). In general, CS and DAIRY farms completing a NMP carried out 0.68 and 0.83 more total actions respectively (**Tables 5.3** and **5.4**). The completion of a NMP is significantly associated with an increased proportion of CS and DAIRY farms claiming to have carried out a number of individual management actions (**Figure 5.1**), with the exception of '*delayed application to avoid spreading to wet or frozen ground*' (*generalised linear model*, P >0.05). This may be explained by legislation and scheme requirements that enforce farmers to carry out this action whether or not a plan is in place. The calculated marginal effects ranged from 7.2% for '*increased use of straight rather than compound fertiliser*' (*generalised linear model*, P 0.04) on CS farms (*generalised linear model*, P 0.04) (**Table 5.3**) to 20.9% for 'testing of soil nutrient status' on DAIRY farms (*generalised linear model*, P<0.01) (**Table 5.4**). There was a stronger effect of having a NMP in place on the uptake of two specific actions on CS farms in 2016. These actions were '*testing of soil nutrient status*' (*generalised linear model*, P <0.01) and '*delayed application to avoid spreading to wet or frozen ground*' (*generalised linear model*, P 0.02) (**Table 5.3**). In contrast, the effect of NMP on the uptake of individual actions is consistent in both survey years for the DAIRY farm type. The completion of a NMP is therefore associated with a greater uptake of individual nutrient management actions for both the CS and DAIRY farms. The marginal effects imply a strong positive association and were generally higher than those observed for the completion of a MMP.

Table 5.3 Coefficients and marginal effects of poisson and binomial models fitted to the total count of nutrient management actions taken by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Total Count of Actions		(Intercept)	0.255	0.065	3.922	0.000
		Year_16	0.312	0.078	4.021	0.000
		Plan	0.387	0.077	5.011	0.000
		AIC:	1223.561			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.555	0.143	3.876	0.000
		Plan	0.684	0.140	4.873	0.000
Binomial Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Calibration of the fertiliser spreader		(Intercept)	-1.023	0.146	-7.018	0.000
		Year_16	0.653	0.224	2.907	0.004
		AIC:	475.660			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.144	0.050	2.877	0.004
Testing of soil nutrient status		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.824	0.183	-4.503	0.000
		Year_16	0.218	0.292	0.747	0.455
		Plan	0.725	0.270	2.679	0.007
		Year_16:Plan	1.203	0.480	2.508	0.012
		AIC:	490.244			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.054	0.072	0.746	0.456
		Plan	0.177	0.065	2.723	0.006
		Year_16:Plan	0.290	0.105	2.753	0.006
Use a fertiliser recommendation system		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.803	0.210	-8.570	0.000
		Year_16	0.755	0.246	3.072	0.002
		Plan	0.798	0.244	3.264	0.001
		AIC:	413.785			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.141	0.047	2.994	0.003
		Plan	0.147	0.046	3.231	0.001

Table 5.3 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of nutrient management actions taken by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Increased use of straight rather than compound fertiliser		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.278	0.229	-9.944	0.000
		Plan	0.654	0.314	2.083	0.037
		AIC:	285.077			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.072	0.035	2.032	0.042
Delayed application to avoid spreading to wet or frozen ground		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.329	0.171	1.928	0.054
		Year_16	-0.069	0.277	-0.248	0.804
		Plan	0.305	0.270	1.130	0.258
		Year_16:Plan	0.982	0.492	1.996	0.046
		AIC:	499.394			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.016	0.064	-0.248	0.804
		Plan	0.070	0.061	1.143	0.253
		Year_16:Plan	0.198	0.083	2.394	0.017

Table 5.4 Coefficients and marginal effects of poisson and binomial models fitted to the total count of nutrient management actions taken by in-scheme DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.835	0.074	11.259	0.000
		Plan	0.308	0.088	3.497	0.000
		AIC:	789.225			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.832	0.227	3.664	0.000
Binomial Model Coefficients and Marginal Effects						
Calibration of the fertiliser spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.596	0.247	-2.414	0.016
		Year_16	1.274	0.369	3.449	0.001
		Plan	0.813	0.296	2.742	0.006
		AIC:	285.731			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.287	0.071	4.025	0.000
		Plan	0.200	0.071	2.800	0.005

Table 5.4 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of nutrient management actions taken by in-scheme DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Testing of soil nutrient status		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.280	0.227	1.234	0.217
		Plan	0.977	0.305	3.203	0.001
		AIC:	260.019			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.209	0.066	3.174	0.002
Use a fertiliser recommendation system		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.545	0.233	-2.334	0.020
		Plan	0.832	0.289	2.878	0.004
		AIC:	299.082			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.204	0.068	2.984	0.003

5.3 Soil Management

Completion of a soil management plan (SMP) was associated with a statistically significant increase in the total number of soil management actions undertaken on grassland fields. This was true of both CS and DAIRY farms that shared similar marginal effects (*generalised linear model*, P <0.01). In general, CS and DAIRY farms completing a SMP carried out 0.93 and 1.01 more total actions respectively (**Tables 5.5** and **5.6**). The completion of a SMP is significantly associated with an increased proportion of CS and DAIRY farms claiming to have carried out a number of individual management actions (**Figure 5.1**), with the exception of '*delayed putting stock out to grass*' and '*no longer out-winter cattle*' (*generalised linear model*, P >0.05). The calculated marginal effects ranged from 9.5% for '*improved drainage on poached fields*' (*generalised linear model*, P 0.01) to 18.9% for '*remove compaction by re-seeding or soil loosening*' on CS farms (*generalised linear model*, P <0.01) (**Table 5.5**). The calculated marginal effects for individual actions were generally larger for the DAIRY farm type, most of which are more applicable to DAIRY farm systems compared to CS farms. This is particularly the case for '*reduced length of grazing season or day*' and '*provided in-field watering points*', where in contrast with CS farms, the completion of a SMP was associated with a statistically significant increase in the proportion of DAIRY farms undertaking these actions (**Table 5.6**).The marginal effects ranged from 15.9% for '*reduced stocking rate on fields subject to poaching*' (*generalised linear model*, P 0.05) to 23.3% for '*fenced off streams from livestock*' (*generalised linear model*, P<0.01) (**Table 5.6**). The effect of having completed a SMP on the uptake of individual actions is consistent in both survey years for the both the CS and DAIRY farms. The completion of a SMP is therefore associated with a greater uptake of individual soil management actions on grassland fields for both the CS and DAIRY farms. This was despite the reduction in the overall number of farms completing SMP between 2009 and 2016 as a result of changes in legislative requirements.

In contrast, the completion of a SMP was only associated with a statistically significant increase in the total number of soil management actions undertaken on arable fields by CS farms (*generalised linear model*, P <0.01). In general, CS farms completing a SMP carried out 1.55 more total actions on arable fields (**Table 5.7**). Although the completion of a SMP is

significantly associated with an increased proportion of CS farms claiming to have carried out 3 individual management actions (*generalised linear model*, P<0.01), it is not a useful predictive variable of practice owing to the relatively low numbers of respondents undertaking actions on arable land. This is reflected in the relatively high marginal effects for '*establishing winter cover by early drilling*', where the effect of having a SMP in place was only observed in 2009, and '*cultivating across slope*', where the effect of having a SMP in place was only observed in 2016 (**Table 5.7**). In addition, the completion of a SMP is not significantly associated with an increased proportion of DAIRY farms claiming to have carried out a number of individual management actions.

Table 5.5 Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on grassland fields by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.095	0.050	21.989	0.000
		Year_16	0.266	0.049	5.436	0.000
		Plan	0.251	0.052	4.866	0.000
		AIC:	2267.813			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	1.077	0.207	5.192	0.000
		Plan	0.928	0.183	5.080	0.000
Binomial Model Coefficients and Marginal Effects						
Reduced stocking rate on fields subject to poaching		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.283	0.186	-1.518	0.129
		Year_16	0.691	0.209	3.305	0.001
		Plan	0.443	0.202	2.194	0.028
		AIC:	672.884			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.166	0.048	3.445	0.001
		Plan	0.110	0.050	2.199	0.028
Improved drainage on poached fields		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.921	0.245	-7.844	0.000
		Year_16	0.952	0.231	4.123	0.000
		Plan	0.574	0.247	2.320	0.020
		AIC:	526.258			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.181	0.046	3.938	0.000
		Plan	0.095	0.038	2.474	0.013

Table 5.5 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on grassland fields by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Remove compaction by re-seeding or soil loosening		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.332	0.212	-6.290	0.000
		Year_16	0.823	0.212	3.890	0.000
		Plan	0.847	0.219	3.867	0.000
		AIC:	639.553			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.197	0.051	3.899	0.000
		Plan	0.189	0.046	4.148	0.000
Fenced off streams from livestock		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.686	0.230	-7.335	0.000
		Year_16	0.752	0.219	3.439	0.001
		Plan	0.931	0.234	3.972	0.000
		AIC:	598.292			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.166	0.049	3.365	0.001
		Plan	0.183	0.042	4.385	0.000
Re-sited or regularly rotated feeding sites		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.475	0.193	-2.466	0.014
		Year_16	1.208	0.224	5.399	0.000
		Plan	0.603	0.210	2.874	0.004
		AIC:	648.447			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.275	0.046	6.040	0.000
		Plan	0.148	0.051	2.889	0.004

Table 5.6 Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on grassland fields by in-scheme DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.275	0.074	17.315	0.000
		Year_16	0.303	0.070	4.342	0.000
		Plan	0.233	0.077	3.027	0.002
		AIC:	1096.144			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	1.512	0.377	4.007	0.000
		Plan	1.006	0.312	3.226	0.001
Reduced stocking rate on fields subject to poaching		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.302	0.299	-1.010	0.312
		Year_16	0.683	0.347	1.970	0.049
		Plan	0.646	0.323	2.003	0.045
		AIC:	311.528			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.158	0.075	2.108	0.035
		Plan	0.159	0.079	2.009	0.045
Reduced length of grazing season or day		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.611	0.285	-2.144	0.032
		Plan	0.702	0.322	2.177	0.030
		AIC:	317.671			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.171	0.075	2.275	0.023
Improved drainage on poached fields		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.004	0.169	-5.951	0.000
		Year_16	0.807	0.328	2.460	0.014
		AIC:	282.357			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.183	0.077	2.370	0.018
Remove compaction by re-seeding or soil loosening		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.982	0.342	-2.872	0.004
		Year_16	2.298	0.457	5.026	0.000
		Plan	0.918	0.367	2.500	0.012
		AIC:	285.813			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.452	0.059	7.645	0.000
		Plan	0.226	0.087	2.593	0.010

Table 5.6 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on grassland fields by in-scheme DAIRY farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Fenced off streams from livestock		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.333	0.344	-3.874	0.000
		Year_16	1.218	0.349	3.493	0.000
		Plan	1.022	0.359	2.850	0.004
		AIC:	302.201			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.295	0.079	3.748	0.000
		Plan	0.233	0.073	3.185	0.001
Provided in-field watering points		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.532	0.311	-1.711	0.087
		Year_16	1.399	0.385	3.631	0.000
		Plan	0.705	0.336	2.099	0.036
		AIC:	302.779			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.301	0.068	4.442	0.000
		Plan	0.174	0.082	2.118	0.034
Re-sited or regularly rotated feeding sites		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.281	0.151	-1.862	0.063
		Year_16	0.974	0.333	2.924	0.003
		AIC:	313.568			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.236	0.076	3.125	0.002
No longer out-winter cattle		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.304	0.151	2.010	0.044
		Year_16	-1.087	0.338	-3.220	0.001
		AIC:	311.507			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.262	0.075	-3.501	0.000

Table 5.7 Coefficients and marginal effects of poisson and binomial models fitted to the total count of soil management actions taken on arable fields by in-scheme CS farms, and the proportion of respondents taking specific actions in the 2009 and 2016 surveys.

Poisson Model Coefficients and Marginal Effects						
Total Count of Actions		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.192	0.077	15.452	0.000
		Plan	0.385	0.089	4.328	0.000
		AIC:	850.040			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	1.546	0.332	4.655	0.000
Binomial Model Coefficients and Marginal Effects						
Established winter cover by sowing cover crop		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.251	0.743	-3.029	0.002
		Year_16	1.983	0.830	2.390	0.017
		Plan	2.251	0.778	2.894	0.004
		Year_16:Plan	-1.849	0.935	-1.977	0.048
		AIC:	209.076			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	0.458	0.164	2.787	0.005
		Plan	0.464	0.117	3.973	0.000
		Year_16:Plan	-0.368	0.130	-2.817	0.005
Cultivating across slope		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.916	0.483	-1.897	0.058
		Year_16	-1.723	0.877	-1.964	0.049
		Plan	-0.405	0.559	-0.725	0.468
		Year_16:Plan	2.639	0.994	2.656	0.008
		AIC:	166.431			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Year_16	-0.252	0.108	-2.339	0.019
		Plan	-0.069	0.099	-0.699	0.485
		Year_16:Plan	0.552	0.188	2.940	0.003
Convert field corners to grass or bird cover		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.015	0.435	-4.636	0.000
		Plan	1.350	0.481	2.809	0.005
		AIC:	176.792			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Plan	0.222	0.064	3.445	0.001

In summary, generalised linear modelling established that the completion of management plans is significantly associated with an increased proportion of CS and DAIRY farms claiming to have carried out a total of 29 individual management actions (**Figure 5.1**). The increases were distributed between MMP (10 of 20), NMP (6 of 10) and SMP (10 of 18). The increased uptake of the number of individual nutrient and soil management actions that are significantly associated with the completion of management plans is consistent for both CS and DAIRY farms. In contrast, the increased uptake of the number of individual manure management actions that are significantly associated with the completion of a MMP is higher on CS farms in comparison to DAIRY farms (**Figure 5.1**). This suggests that having a MMP in place is a more useful diagnostic of good practice for CS farms than for DAIRY farms.

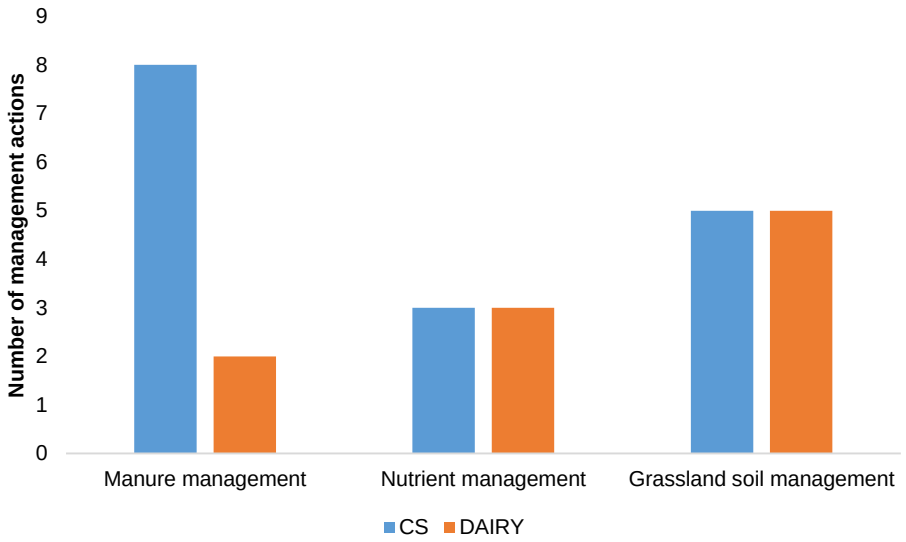

Figure 5.1 The number of individual management actions significantly associated with the completion of respective management plan, stratified by management plan type.

Completion of all three management plans are associated with a statistically significant increase in the total number of management actions carried out in the past three years and an increase in the proportion of farmers reporting an uptake in individual actions. This is despite a decrease in the overall number of farms completing soil management plans between 2009 and 2016 as a result of changes in regulatory requirements. The marginal effect of having a plan on individual actions range from 3.7 to 29% and broadly supports the positive conclusion that completion of management plans is diagnostic of action.

6. Synthesis of Survey Results

A survey of changing farm practices associated with participation in the Glastir and preceding Tir Cynnal and Tir Gofal agri-environment schemes was commissioned by Welsh Government as part of the Glastir Monitoring and Evaluation Programme (GMEP) led by the Centre for Ecology and Hydrology (CEH) (**Emmett *et al*., 2014**). The Glastir scheme land management options and Advanced level spatial prioritisation and selection process will evolve with changing policy priorities and emerging evidence on the effectiveness of options. Computer modelling of scheme outcomes for diffuse water pollution and climate change at catchment and regional scale will be a key decision making tool in this process, to complement the field scale ecological monitoring that is being carried out under the GMEP. The first objective of this survey was therefore to establish farm level changes in management for diffuse pollution control that are claimed by farmers as a direct response to the Glastir management options, and to establish the background level of change on non-scheme farms in response to other drivers for change, including farm economics. The recorded changes were used as input to a diffuse pollution model to calculate the catchment and regional impact of Glastir in a separate exercise (Gooday and Whitworth, 2017).

The survey also aimed to provide evidence and act as an indicator for two of the six strategic Glastir objectives (**Auditor General for Wales, 2014**):

- *To increase the level of investment into measures for climate change adaptation with the aim of building greater resilience into both farm and forest businesses and the wider Welsh economy and environment to ongoing climate change; and*

- *To use agri-environment investment in way that encourages positive environmental outcomes but also contributes towards farm and forest business profitability and the wider sustainability of the rural economy.*

In response to these strategic objectives, the survey collected information on changes in management and on the level of farmer interest in on-farm energy and renewables production, woodland creation and management, and farmer perceptions of how participation in the Glastir scheme had supported climate change adaptation and the enhancement of farm business profitability.

A total of 601 farms were surveyed and were stratified on the basis of level of scheme participation in the previous Tir Cynnal and Tir Gofal schemes, and the current Glastir Entry and Glastir Advanced schemes, and on the basis of farm type (see Section 3 of **Anthony and Stopps, 2016**). The surveyed farms were stratified across DAIRY, CS-SDA and CS-DA+CS-LOW farm types and were representative of the range of farm sizes in Wales. Compared to the June Agricultural Survey (2015), the regional distribution of the number of farms of each farm type was well represented in this survey. The surveyed farms managed a total area of 68,600 ha, of which 55% was improved grassland and 6% was arable land. Rough grazing accounted for 34% of the total land area. More than 1 ha of woodland was found on 56% of respondent's farms.

Farmers contacted to take part in the survey were given the opportunity to opt out. The overall refusal rate by farmers that were contacted was just 19%. There was no statistical evidence that the farms refusing to participate in the survey differed in output from the participating farms.

The results presented in this synthesis are for the surveyed populations of dairy and beef cattle & sheep farms, or an average value for all farms that were surveyed. The survey achieved returns from 141 DAIRY farms, 230 CS-DA+CS-LOW, and 230 CS-SDA farms. In

the national population of all grazing livestock farms in Wales, dairy farms account for only 16% of the total farmed area. No attempt has been made to adjust the survey results to represent the national ratio of dairy to cattle & sheep farms in Wales. Disaggregated and appropriately scaled results are available.

6.1 Diffuse Pollution Control

Nutrient Management

Nutrient Management Plans (NMP) aim to improve the efficiency of nutrient use on farms. By matching nutrient inputs to crop demand, NMP help to optimise yield, minimise nutrient use and reduce losses of nutrients to the environment. An NMP consists of a budgeting procedure for the whole farm and individual fields in order to meet the need of current crops whilst taking account of all sources of nutrients including residual effects of previous cropping. It is aided by soil testing, calibration of equipment and using recommendation systems.

The proportion of beef cattle and sheep farms using manufactured fertiliser was 71%, whereas the proportion of dairy farms using fertiliser was 89%. This survey found that 56% of farms using fertiliser had an NMP. Overall, 49% of beef cattle and sheep farms and 73% of dairy farms had an NMP and 60% of respondents completed these themselves. The 2016 farm practices survey for England (**Defra, 2016**) reported that a comparable 72% of dairy farms in England had an NMP, whereas only 27% of beef cattle and sheep farms had an NMP. A large proportion of respondents (42%) sought professional advice to supplement their own knowledge or experience to assess the nutrient requirements of crops and grassland. However, relatively few farms (7%) use decision support tools themselves, such as RB209 or PLANET. These values were generally larger on the dairy farms compared to the beef cattle and sheep farms (59 vs 36% and 14 vs 5%), suggesting that dairy farmers were more likely to use professional advice and tools in completing a NMP.

The majority of farms have access to livestock manures and whilst this is an important part of the nutrient budget of the farm, only 20% of respondents sought professional advice or carried out manure testing to assess the nutrient value of spread manures. Furthermore, another 20% of respondents stated that they do not assess the nutrient value of spread manures. The majority of farmers tested fields for soil nutrient status (63%) and tested fields for pH and liming (65%) every three years or more, and there was no significant association with scheme participation.

Figure 6.1 shows the percent of respondents having completed management plans stratified by scheme participation. This survey found that participants in the Glastir scheme were more likely to have completed a NMP than non-scheme farms (59 vs 41%). It also found a legacy of having participated in the preceding Tir Cynnal scheme (72 vs 41%), which can be related to scheme legislation that enforced participants who applied inorganic or organic fertiliser to the agreement land to produce a NMP under a farm Resource Management Plan (**Welsh Assembly Government, 2005d**). The level of uptake was similar to that of the general population of all farms in England. The Defra Farm Practices Survey has reported uptake in the range 49 to 61% in the period 2007 to 2016.

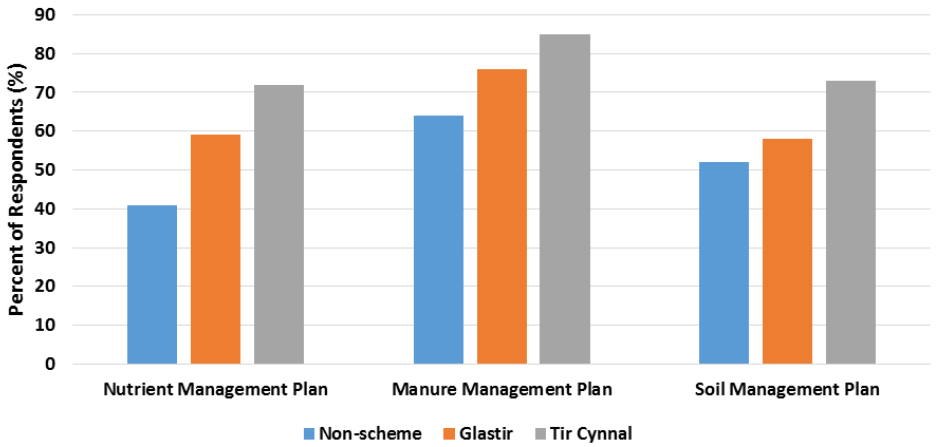

Figure 6.1 Proportion of respondents using fertiliser and completing management plans averaged across all surveyed farms, stratified by current and preceding scheme participation.

Survey participants were asked whether they had implemented one or more of 5 individual nutrient management actions. Participants in the current Glastir scheme claimed to have carried out a greater total number of nutrient management actions in the last three years compared to non-scheme farms (**Figure 6.2**). This was consistent across both the dairy and beef cattle and sheep farms. Overall, there was a statistically significant +0.3 actions per farm participating in the Glastir scheme. There was also a legacy of having participated in the preceding Tir Cynnal scheme, with an additional +0.4 increase in the total number of number management actions undertaken in the last three years, relative to the non-scheme farms surveyed in 2016.

Uptake of individual fertiliser management actions on the dairy farms ranged from 40 to 82%, whilst uptake on the beef cattle and sheep farms was generally lower and ranged from 21 to 68%. Examples being a greater proportion of dairy farmers controlled fertiliser applications by calibrating fertiliser spreaders (74 vs 48%) or delaying the timing of application (78 vs 68%) compared to beef cattle and sheep farms. Participation in the Glastir scheme specifically raised the uptake of soil nutrient testing (61 vs 51%), calibration of fertiliser spreader (72 vs 62%) and delaying application to avoid spreading to wet or frozen ground (77 vs 65%) relative to non-scheme farms. Whilst the latter action is a direct requirement of the Whole Farm Code in the Glastir scheme, other actions are more likely to be associated with Glastir scheme participation rather than a direct result of scheme requirements.

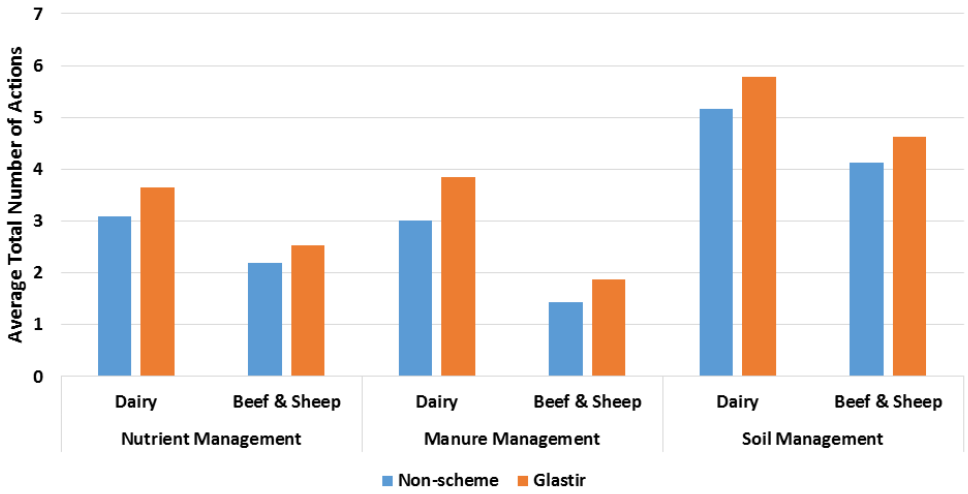

Figure 6.2 Average total number of management actions taken by non-scheme and Glastir scheme participants stratified by farm type.

An important aspect of Glastir participation has been a net reduction in fertiliser use as a result of management options and change in stocking rates and therefore the need to produce forage. Overall, Glastir participants recorded net reductions of 8.5 and 9.4% in the use of phosphate and nitrogen fertiliser on grassland fields respectively, with similar values for each farm type (**Table 6.1**). Fewer than 5% of Glastir participants recorded an increase in the use of either nitrogen and phosphate fertiliser on entry to the scheme, with the majority (between 34 and 41%) recording decreases. The reduction in nitrogen fertiliser use on grassland fields is comparable in magnitude to the net reduction occurring on non-scheme farms. According to the questionnaire design, the change due to scheme entry and background rate of change ought to be independent and additional. However, a high percentage of respondents cited fertiliser cost (50%) and change in stock numbers (37%) as a factor influencing their decision on scheme entry and therefore the effect of Glastir scheme participation cannot be considered as totally independent and in addition to the changes recorded on non-scheme farms. Similar reductions were observed for fertiliser use on arable fields, but the number of respondents that had arable land on their farm was small, so the reductions carry less confidence. However, taken together, it is expected that this reduction in fertiliser use would have a noticeable impact on pollutant emissions and losses within catchments where scheme participation was high.

Table 6.1 Net percentage change in nitrogen and phosphate fertiliser use on typical improved grassland fields in the previous three years for non-scheme farms and farms explicitly reporting change on entry to the Glastir scheme, stratified by farm type.

Farm type	Scheme	Nitrogen fertiliser	Phosphate fertiliser
Dairy	Non-scheme	-5.4 (-8.6 to -2.3)	-3.3 (-6.7 to -0.6)
	Glastir	-8.8 (-15.0 to -3.0)	-13.7 (-21.3 to -6.9)
Beef and Sheep	Non-scheme	-9.7 (-15.3 to -4.5)	-5.2 (-9.8 to -1.4)
	Glastir	-8.3 (-13.0 to -3.7)	-7.9 (-11.6 to -3.5)

Manure Management

Manure Management Plans (MMP) aim to minimise the risk of diffuse pollution by enforcing farmers to undertake a spatial risk assessment for the storage and spreading of manures, slurry, dirty water and other organic wastes on the farm and to adopt improved spreading practices. A MMP helps farmers identify when, where and at what rate to spread manures and to assess whether they have enough storage or useable spreading area.

The proportion of surveyed farms with livestock was 98%. In contrast to previous reporting on the first Wales Farm Practices Survey (**Anthony *et al*., 2012**), all these farms were included in this analysis, and not just farms with cattle. The reporting of the previous survey restricted the analysis to cattle as sheep generate comparatively little managed manure. We found that 30% of surveyed cattle & sheep farms were stocked with sheep only, and this may result in a comparatively lower level of reported uptake of some actions.

This survey found that 76% of farms with livestock had completed a MMP. Overall, 70% of the surveyed beef cattle and sheep farms and 90% of dairy farms in Wales had a MMP in place and 76% of respondents completed the plans themselves. Again, this level of uptake was similar to that of the general population of all farms in England. The Defra Farm Practices Survey has reported uptake in the range 62 to 71% since 2009, the 2016 survey reported that 48% of beef cattle and sheep farms, and 90% of dairy farms had completed a MMP (**Defra, 2016**).

Figure 6.1 shows that participants in the Glastir scheme were more likely to complete a MMP than non-scheme farms (76 vs 64%). The survey also found a legacy of having participated in the preceding Tir Cynnal scheme (85 vs 64%), which can be related to scheme legislation that enforced participants who produced, stored or disposed of slurry, farmyard manure or other organic waste on the agreement land to produce a MMP under a farm Resource Management Plan (**Welsh Assembly Government, 2005c**).

Survey participants were asked whether they had implemented one or more of 10 individual manure management actions. Participants in the current Glastir scheme claimed to have carried out a greater total number of manure management actions in the last three years compared to non-scheme farms (**Figure 6.2**). Overall, there was a statistically significant +0.7 actions per farm participating in the Glastir scheme. However, despite having an effect on completion of the MMP there was no effect of previous Tir Cynnal participation on the count of actions relative to the non-scheme farms surveyed in 2016.

Uptake of individual manure management actions on the dairy farms ranged from 11 to 63%, whilst uptake on the beef cattle and sheep farms was generally lower and ranged from 2 to 34%. Although the magnitude of uptake was lower than for the nutrient management actions, the differences in uptake between the beef cattle and sheep and dairy farms are similar. Participation in the Glastir scheme was associated with a higher proportion of farmers *increasing the size of slurry store* (14 vs 8%), *covering manure heaps* (14 vs 7%) and *calibrating manure spreader* (25 vs 18%) relative to non-scheme farms.

This survey also recorded a statistically significant reduction in the number of breeding ewes (5.8%) on entry to the Advanced level of Glastir, but no change in cattle numbers, with changes occurring on 25% of the participating farms. As sheep generate relatively little managed manure, the change in ewe numbers would have only a small impact on the total quantity of manure managed and is unlikely to have a noticeable impact on emissions from manure within any single catchment. Further significant net reductions in sheep numbers of a similar magnitude were recorded in non-scheme farms over the past 3 years, in response to changing market conditions and availability of land to rent. Although the net change was similar to the effect of Glastir scheme entry, a greater proportion of non-scheme farms

reported an expansion and increase in ewe numbers (15 vs 5%) that was balanced by a greater proportion reporting a decrease (30 vs 20%).

Soil Management

The purpose of a soil assessment or protection plan is to prevent degradation threats to soil which arise from high stocking rates, use of machinery and poor timing of practices during detrimental weather events. When soil is lost or damaged through erosion, compaction or loss of organic matter it becomes less productive. It can have a significant impact on water quality and aquatic ecosystems and contribute to localised flooding from increased runoff (**Defra, 2009**).

Since the first Wales farm practice survey in 2009, there has been a change in legislative requirements relating to cross compliance soil management rules. The most notable change concerned the previous requirement under GAEC to complete and retain a Soil Protection Review (SPR) / soil assessment record. This is no longer a requirement and has been replaced by a new set of national minimum standards. As a result the proportion of farms completing a soil assessment or protection review has significantly reduced from 78% in the 2009 survey of Welsh farming practice (**Anthony *et al.,* 2012**) to 58%. Overall, 55% of beef cattle and sheep farms and 68% of dairy farms had a soil assessment or protection review in place and 74% of respondents completed these themselves.

Figure 6.1 shows that participants in the Glastir scheme were more likely to have completed a soil assessment or protection plan than non-scheme farms (58 vs 52%). The survey also found a legacy of having participated in the preceding Tir Cynnal scheme (71 vs 52%), which can be related to scheme legislation that required farmers to complete a Resource Management Plan. Aspects of soil management were also included under Cross Compliance and the Single Payment Scheme (superseded by Basic Payment Scheme in 2015) (**Welsh Assembly Government, 2005c**).

Survey participants were asked whether they had implemented one or more of 9 grassland and 13 arable individual soil management actions. Participants in the current Glastir scheme claimed to have carried out a greater total number of soil management actions in the last three years compared to non-scheme farms (**Figure 6.2**). Overall, there was a statistically significant +0.5 actions per farm participating in the Glastir scheme. There was no effect of previous Tir Cynnal participation on the count of actions relative to the non-scheme farms surveyed in 2016.

Uptake of individual soil management actions on grassland fields by dairy farms ranged from 30 to 85%, whilst uptake on the beef cattle and sheep farms was generally lower and ranged from 27 to 66%. The differences in uptake between the beef cattle and sheep and dairy farms are smaller than recorded for the nutrient management actions.

Participation in the Glastir scheme, and more specifically the advanced level of Glastir, raised the uptake of two individual grassland soil management actions involving fencing off streams from livestock (68 vs 39%) and re-siting or regularly rotating feeding sites (76 vs 58%) relative to non-scheme farms. The former of these management actions directly relates to the Glastir scheme management prescription “streamside corridor management” (No. 173) that restricts livestock from entering stream corridors. As the advanced level of the Glastir scheme is competitive, it enables participants to access greater financial support to undertake particular management options. Therefore, it is likely that these actions are a result of scheme participation rather than being associated with participation as was seen with manure management actions.

Furthermore, participation in the advanced level of the Glastir scheme specifically raised the uptake of leaving stubble in fields (59 vs 44%) and participation in the Glastir scheme (both entry and advanced) raised the uptake of establishing vegetated and uncultivated buffer strips (42 vs 16%), both on arable land. These actions can be directly related to Glastir scheme management options relating to over-winter cover and riparian buffer zones to prevent erosion and run-off from land under arable cropping.

6.2 Farm Resilience

Resilience is defined as the ability of a farm business to survive and adapt to volatility in agricultural markets and to infrequent environmental risks, especially those linked to climate change. Resilience relies heavily on the skills and enterprise of individual farm managers, but the knowledge, financial and organisational support provided through participation in an agri-environment scheme may advance the implementation of relevant strategies.

Climate Change Adaptation

Climate change projections for Wales of increasing summer temperatures and winter rainfall present a business risk to farms vulnerable to events that are at present relatively infrequent. The principal threats are drought and flooding, but livestock may also be increasingly affected by heat stress, whilst higher spring rainfall may delay livestock turn-out and increase expenditure on bought-in feeds and increase rates of soil erosion, and there may be some impact on the prevalence of pests and diseases. Relevant adaptations for the mitigation of risk include the introduction of drought resistant forage varieties, provision of shade for livestock and planning forage production for extended housing periods, and seasonal risk assessment and preventative veterinary treatments.

Table 6.2 Percentage (%) of farms taking action for adaptation to climate change threats, by farm type and threat (n 508).

	Climate Change Threat					
Farm Type	**Flooding**	**Drought**	**Soil Erosion**	**6.2Biodiversity**	**Pests and Disease**	**Heat Stress**
Dairy	9	9	22	13	27	36
Beef & Sheep	9	7	13	11	20	18

This survey of Welsh farmers has shown that between 7 and 36% of farms had taken action to combat specific climate change threats in the past 3 years (**Table 6.2**). These results are similar to earlier surveys of farms in England, most notably the Farming Futures survey that reported that 22% of sheep, 17% of beef cattle and 31% of dairy farms claimed to be taking action to adapt to the impacts of climate change (**Farming Futures, 2011**). The majority of actions were focused on management of pests and diseases, and of heat stress in livestock (**Figure 6.3**). Overall, 36% of dairy farms and 18% of beef cattle and sheep farms reported having taken action on heat stress in livestock. Respondents had taken an average of 1 action per farm, but a high proportion took no action to adapt to climate change (58%) whilst others took multiple actions.

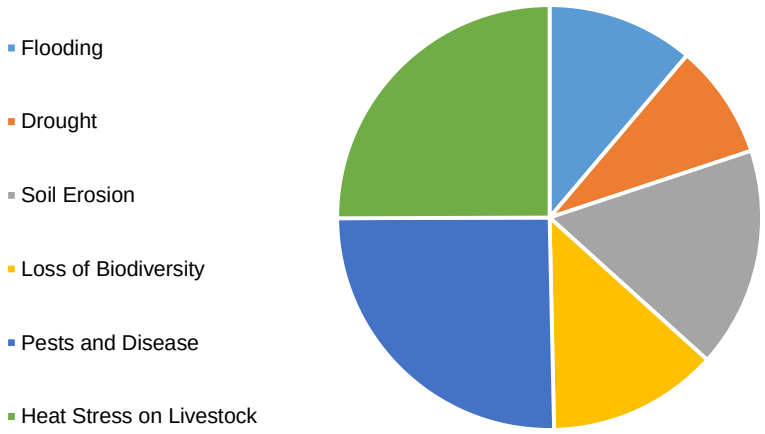

Figure 6.3 Share of actions taken by respondents for adaptation to climate change threats (*n* 508).

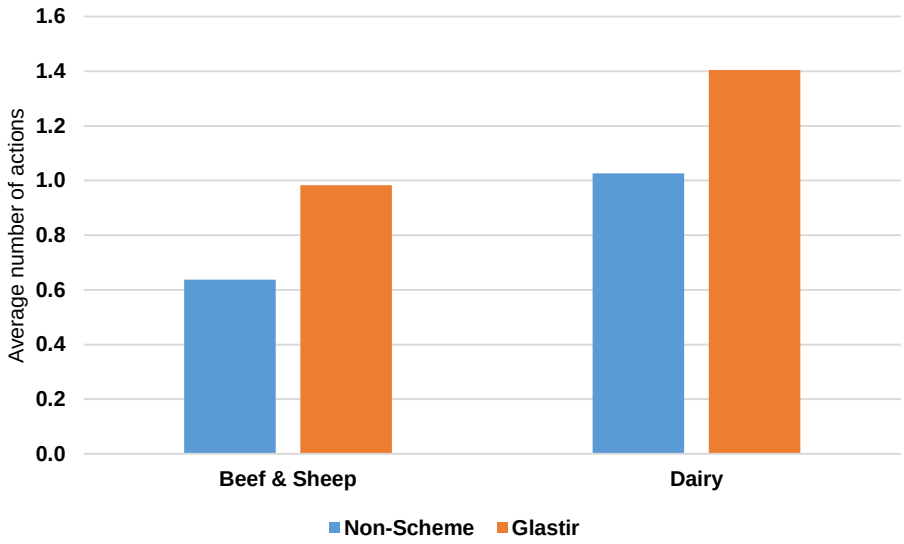

Figure 6.4 Average number of actions per farm taken for adaptation to climate change threats, by farm type and scheme participation, all surveyed farms (n 508).

Participation in Glastir was associated with a greater number of farms carrying out action to combat soil erosion (19 vs 11%) and biodiversity loss (19 vs 6%) compared to non-scheme farms, which is consistent with the focus of management options under Glastir. Participants in Glastir were also more likely to have invested in on-farm renewable energy production (36 vs 21%) compared to non-scheme farms, generally from solar photo-voltaic panels, although it is suspected that this is an attribute of the participants rather than an effect of scheme. A majority (70%) of farms participating in Glastir and who had taken action also explicitly acknowledged the support provided by the scheme. This included provision of relevant information (72%) and receipt of grants for capital investment (53%). The support provided by the Glastir scheme encouraged farmers to bring forward actions already planned (56%), and encouraged collaboration with other farms (29%). Adaptation was unlikely to be a direct

result of the Glastir scheme requirements, but could have a resulted from the knowledge exchange and income generated by scheme participation.

Business Improvement

Many livestock farms in Wales fail to achieve a sustainable farming livelihood each year and there is a continuous desire to improve the commercial success of farm businesses. This can be partly achieved by improvements in production and resource efficiency, through the introduction of new machinery and practices, and also the adoption of enterprise diversification and insurance against changing markets.

Table 6.3 Percentage (%) of farms taking action for business improvement, by farm type and aspect of resource efficiency and diversification (n 508).

	Aspect of Business Improvement				
Farm Type	**Fuel & Energy Efficiency**	**Nutrient Efficiency**	**Animal Health**	**Diversification**	**Water Use Efficiency**
Dairy	59	62	79	23	51
Beef & Sheep	28	32	62	23	26

This survey of Welsh farmers has shown that between 23 and 79% of farms had taken action to improve aspects of the farm business in the past 3 years (**Table 6.3**), a finding similar to an earlier survey of the introduction of new farm practices in England (**Farm Business Survey, 2016**). The overall average was around 2 actions per farm, with the majority (67%) having taken at least one action.

Farms participating in Glastir had carried out a greater number of actions than non-scheme farms (**Figure 6.6**). This was true of both dairy and beef cattle & sheep farms, although the improvement was small (16 to 20%) over the non-scheme baseline. Participation in Glastir was associated with a greater number of farms carrying out action to improve nutrient efficiency (45 vs 34%), and business diversification for farms in the Advanced level of the scheme (36 vs 19%). There was no reliable evidence of an associated change in the overall number of persons employed on farm, although farm diversification was most frequently associated with any increase in persons employed, and a decrease was most frequently associated with the need for cost savings (58%) or the withdrawal of a grant (26%)

A majority (55%) of farms participating in Glastir and who had taken action also explicitly acknowledged the support provided by the scheme. This included provision of relevant information (77%) and receipt of grants for capital investment (57%). Acknowledgement of financial support was higher for the Advanced over the Entry level of the scheme. The support provided by the Glastir scheme encouraged farmers to bring forward actions already planned (60%) and encouraged collaboration with other farms (27%).

Action was not necessarily a direct result of the Glastir scheme requirements, and could have a resulted from a change in farm business strategy that took account of both the management requirements and income generated by scheme participation.

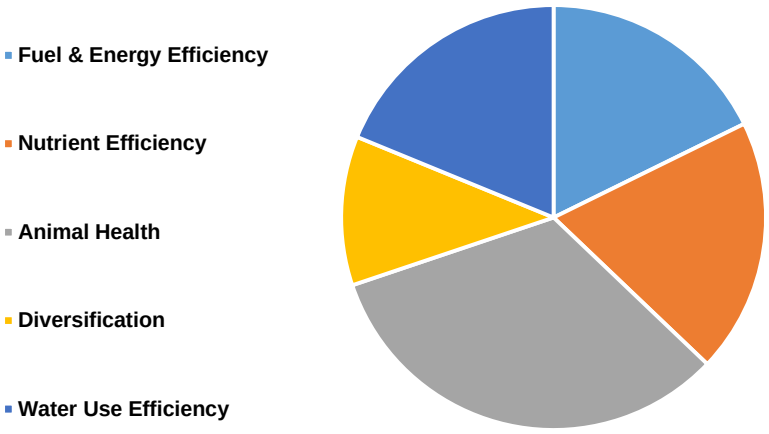

Figure 6.5 Share of actions taken by farm managers for business improvement, by aspect of resource efficiency and diversification, all surveyed farms (n 508).

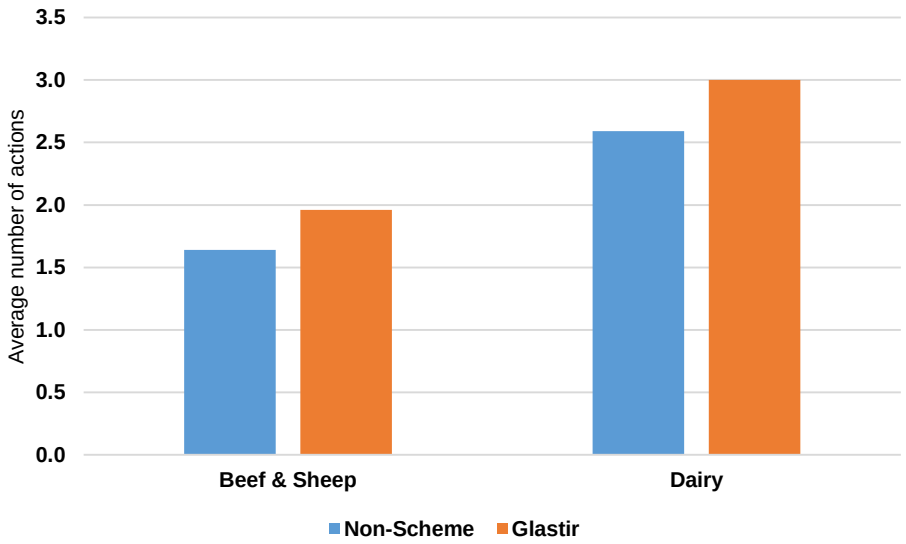

Figure 6.6 Average number of actions per farm taken for business improvement, by farm type and scheme participation, all surveyed farms (n 508).

6.3 Woodland Management and Renewable Energy

Woodland Management

The Welsh Government is committed to planting an additional 100,000 ha of woodland by 2020 to provide ecosystem services, especially relating to wildlife habitat and carbon sequestration (**National Assembly for Wales, 2013**). Farms presently manage one quarter of the woodland area, and much of the new woodland is likely to be planted on farm land as it accounts for 71% of the land in Wales.

As expected, a majority (77%) of respondents participating in the Glastir scheme had woodland on their farm, with an average area of 8 ha per farm. They were more likely to have woodland compared to non-scheme farms.

Overall, 16% of all survey respondents had restored or created woodland in the past three years. Glastir scheme participation and receipt of a grant for woodland management was associated with a statistically significant higher number of farmers restoring or creating woodland. This has resulted in woodland restoration on 5% of farms in Glastir and creation on a further 15%. Survey responses indicate that this would not have occurred within the scheme support.

The majority (87%) of survey respondents managed their woodland for one or more services (**Figure 6.7**). Whilst active management of woodland for service provision included a mix of private and public goods, such as provision of firewood and watercourse protection (44% and 40% of farms with woodland), it typically did not include public access to woodland areas by way of education, or sports and recreation (9% and 4% of farms with woodland).

The most frequent services were wildlife habitat (62%) and livestock shelter (52%). Farms participating in the Glastir scheme were less likely to manage their woodland for livestock shelter, and more likely to manage for wildlife habitat. This balancing of services reflects the focus of the scheme options on fencing to exclude stock from habitat areas, prevent the under-grazing of woodland and to permit the expansion of woodland edge.

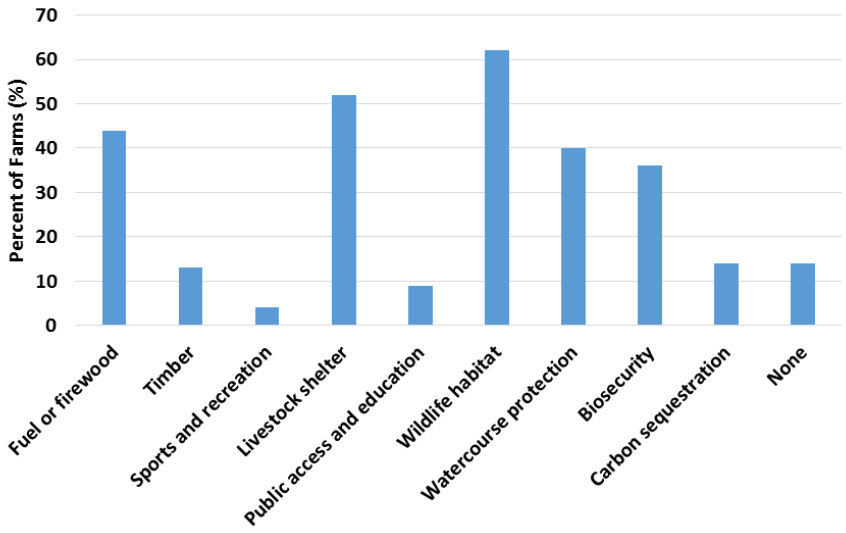

Figure 6.7 Percent of survey respondents with woodland actively managing part or all of their woodland area for specific services.

Renewable Energy

Renewable energy generation is a potentially important strategy for mitigating climate change, complementing woodland creation and carbon sequestration.

This survey found that 28% of surveyed grazing livestock farms generated some form of renewable energy, generally from solar photovoltaic installations, with an average capacity of 33 kW.

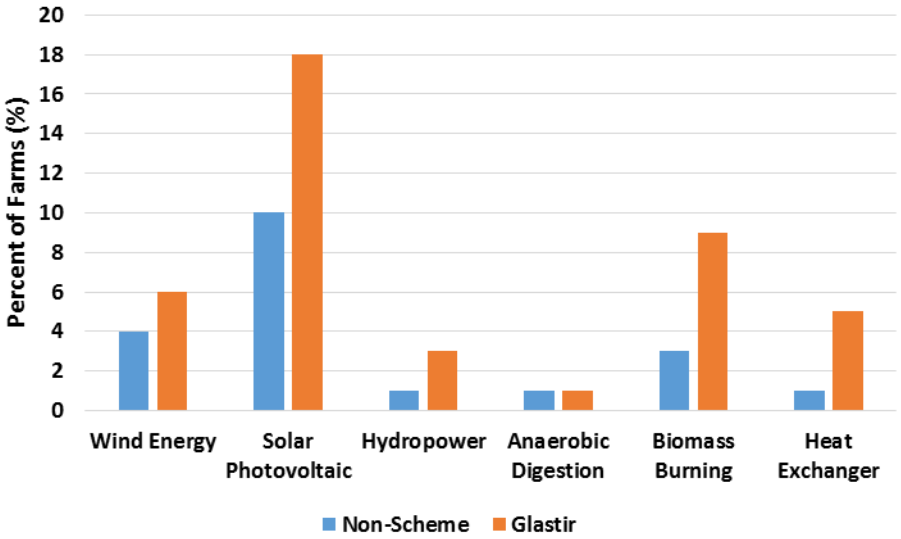

Figure 6.8 Percent of survey respondents with an existing renewable energy installation, stratified by current scheme participation.

Installation of renewable energy was not affected by farm type but was significantly higher on farms participating in the Glastir scheme (**Figure 6.8**). There is no reason to expect Glastir to have an effect on renewables installation as there is no supportive mechanism, and it is believed that this effect was an attribute of the type of farm or farm manager entering scheme.

When the survey results were scaled to all farms in Wales, the current installed capacity was sufficient to off-set a calculated 1% of net greenhouse gas emissions from agriculture in Wales. This finding is consistent with independent carbon foot-print studies that found that on-farm energy usage accounts for less than 5% of the total carbon footprint of farms in Wales (**Anthony *et al*., 2012**; **Taft *et al*., 2015**). A movement away from solar photovoltaics towards wind power and export of the energy produced would increase the potential for on farm renewable energy generation, but this would depend upon the relaxation of planning restrictions and external financial incentives, and improvements to the capacity of the local distribution network so that a majority of farms could export energy.

6.4 General Management Change

This survey recorded farm manager's own assessment of management change and perceived farm outcomes. Overall, 34% of respondents agreed or strongly agreed that participation in the Glastir scheme had '*changed my management of the farm*' (**Figure 6.9**). This can be contrasted with 61% of participants in the preceding Tir Cynnal or Tir Gofal schemes (**Anthony *et al*., 2012**). The response by the Glastir participants was unaffected by any history of participation in the previous schemes, supporting a conclusion that the Glastir scheme is genuinely perceived to have resulted in less change in farm management than the preceding schemes. This likely reflects the survey taking place only a few years after the scheme was begun, but also supports our own opinion that the previous schemes that demanded completion of farm resource management plans were more demanding at the time of first entry. There is also some community perception of Glastir having lower return-on-effort in comparison to the preceding Tir Gofal, and this may have resulted in farms entering scheme that required fewer changes to existing management.

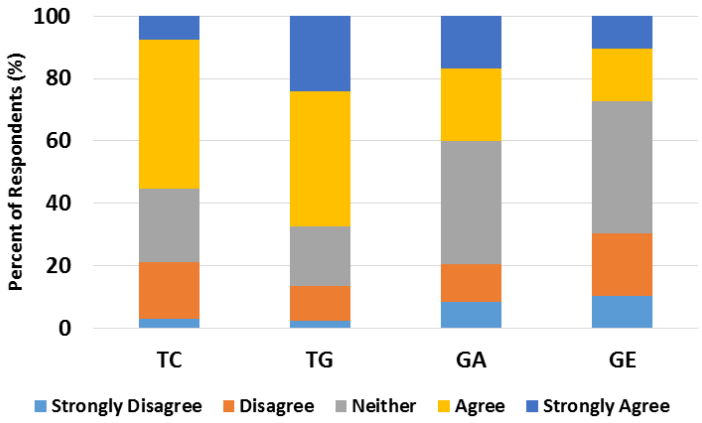

Figure 6.9 Cumulative percent of 1st and 2nd Wales Farm Practice Survey respondents agreeing with the statement that participation in an agri-environment scheme had 'changed my management of the farm', stratified by scheme: Tir Cynnal (TC); Tir Gofal (TG); Glastir Entry (GE); and Glastir Advanced (GA).

Table 6.4 Percent of Glastir participants agreeing or disagreeing that participation had a positive impact on farm outcome.

	Business Health	Future Planning	Water Pollution	Climate Change	Plants and Wildlife	Farm Appearance
Strongly Disagree	14	15	16	15	6	13
Disagree	19	22	18	25	11	13
Neither	34	32	29	32	21	21
Agree	24	22	24	20	39	32
Strongly Agree	10	8	13	8	23	21

Nevertheless, farms participating in the Glastir scheme specifically reported that participation had enabled them to carry out farm improvements to field boundaries, including secure fencing, the rebuilding of stone walls and restoration of hedgerows and the receipt of grant payments enabling this work or contributing to the farm business. These boundary improvements were recognised as supporting wildlife and providing livestock shelter, and were described by respondents as having made a positive contribution to the appearance and general tidiness of farms.

Survey respondents also scored perceived outcomes from scheme participation. The outcomes were organised into pairs: a) '*improved the health of my farm business*' and '*helped me to plan for the future of my farm*'; b) '*reduced my farms contribution to the pollution of rivers and lakes*' and '*reduced my farms contribution to climate change*'; and c) '*enhanced the plants and wildlife on my farm' and 'improved the appearance of my farm*'. The outcome pairs were intended to capture aspects of improvements to the finances and management of the farm business, reductions in the chronic and 'invisible' diffuse pollution of waters, and improvements in the 'visible' environment of the farm.

The percent of Glastir participants who agreed or strongly agreed with statements that the scheme had a positive impact on outcomes varied from 28 and 62% for farms participating in Glastir (**Table 6.4**). Agreement was significantly higher for the '*enhanced the plants and wildlife on my farm*' and '*improved the appearance of my farm*' outcome pair on farms currently participating in the higher level Glastir Advanced scheme. For all perceived outcomes, the distributions of farmer responses were strongly positively correlated (coefficients of 0.36 to 0.55) with the agreement scores for '*change in management of my farm*'. That is, farm managers that agreed that change in management had occurred were also more likely to agree that there had been positive outcomes (**Figure 6.10**). Although there is a risk that investment of time and effort in management change may automatically generate an assumption of positive outcomes, a more supportive conclusion is that where change does occur then benefits are recognised by farm managers and future work should aim to bring about management change on a higher proportion of farms.

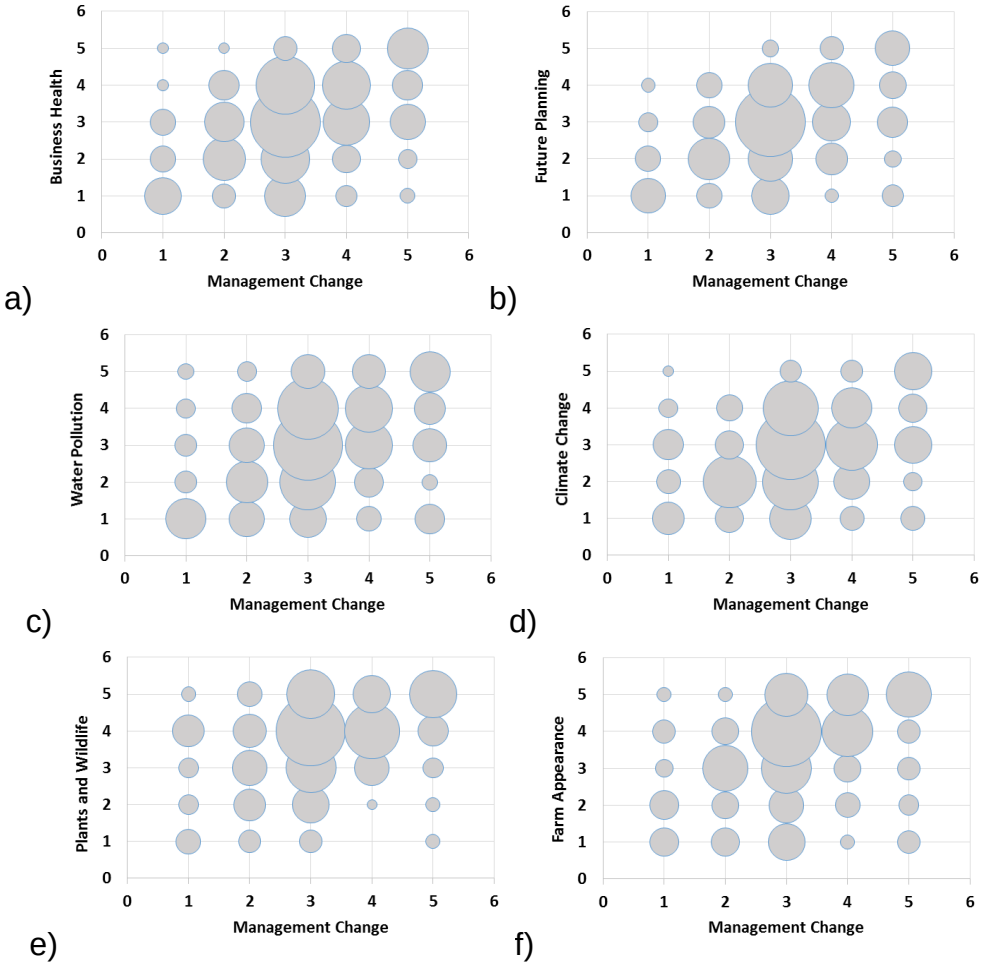

Figure 6.10 Correlation between perception scores for farms participating in the Glastir scheme, for self-assessed '*change in my management of the farm*' attributed to scheme participation and perceived scheme outcomes including a) '*improved business health*'; b) '*helped plan for the future*'; c) '*reduced water pollution*'; d) '*reduced farm contribution to climate change*'; e) '*enhanced plants and wildlife*'; and f) '*improved farm appearance*'. Circle area is proportional to the number of respondents.

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