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GLASTIR MONITORING & EVALUATION PROGRAMME

FINAL REPORT – Annex 3

Wales Farm Practices Survey

Statistical Analysis and Main Results

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Contents

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 second interim report presents the context, main results tables and statistical analyses from a stratified survey of changing farm inputs and management at whole-farm level that are attributed to the Glastir scheme, and farmer perceptions of how the scheme has contributed to climate change adaptation and the enhancement of farm business profitability. The analyses take account of the history of scheme participation, and explicitly compare practices with non-scheme farms and with farms that had participated in the preceding Tir Cynnal or Tir Gofal schemes. A third interim report will compare results with an earlier survey (**Anthony, 2012**) and provide an interpretation of the survey results in relation to scheme prescriptions.*

1. Introduction

A survey of changing farm practices attributable to 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**). This second interim report presents the main results tables and statistical analyses of differences in management between farm types and levels of scheme participation. The results are presented thematically:

Section 2 presents an overview of the statistical approach taken, with **Appendix A** listing the generic scripts used.

Section 3 presents an analysis of change in the number of farm employees.

Sections 4 and 5 present the changes in livestock numbers and fertiliser inputs due to scheme entry and exit.

Sections 6 to 8 present analyses of the uptake of individual nutrient, manure and soil management plans and the uptake of specific mitigation actions for the control of diffuse air and water pollution.

Section 9 presents an analysis of the extent of on-farm woodland restoration and creation and the services delivered by woodland.

Section 10 quantities the current and potential future extent of on-farm renewable energy generation.

Section 11 presents an analysis of farm actions to improve climate and business resilience.

Section 12 presents an analysis of farmer perception of the extent of farm management change and outcomes under Glastir participation.

Section 13 concludes with an analysis of reasons for non-participation and elicited comment on how Glastir might be improved.

2. Method of Analysis

Empirical confidence intervals for the surveyed proportions and counts per farm or respondent were estimated by bootstrap re-sampling with replacement (**Davison and Hinkley, 1997**). Differences in proportions and ranked values between survey strata were tested using the Fisher Exact (**Fisher, 1954**) and Kruskal-Wallis (**Kruskal and Wallis, 1952**) tests. Post-hoc multiple pair-wise comparisons of factors were made using the multiple comparison Fisher Exact test (**Herve, 2016**) and **Dunn (1964)** test, with appropriate **Benhamini and Hochberg (1995)** adjustments to the significance probabilities.

The effects of farm type and scheme participation on surveyed proportions were further modelled by generalised linear modelling with a binomial distribution and logit link function. Surveyed counts were modelled with a poisson distribution model except where there is evidence of over dispersion and a negative binomial distribution is used. Responses to the Likert questions were modelled using ordinal regression. Model identification first considered the main effects and all first order interactions between predictors, with both forward and backward search to find the model with the lowest Akaike Information Criterion (AIC) score that penalises for the number of predictors (**Akaike, 1973**). Potential interactions between the remaining significant predictors were then assessed. Model explanatory power was measured using the **McFadden (1974)** pseudo R^2 and the **Tjur (2009)** coefficient of discrimination. Goodness of fit was assessed at the group level. Marginal effects of predictors were calculated for the mean values of the survey data.

All analyses were carried out using the R statistical package (*version* 3.3) and the 'STATS' (**R Core Team, 2013**), 'MASS' (**Ripley, 2015**), 'ORDINAL' (**Christensen, 2015**), and 'MFX' (**Fernihough, 2015**) libraries. Summary statistics are generally reported by farm type and by scheme participation history. Unless explicitly stated, all confidence intervals in results tables are the ninety-five percent interval.

Changes made to the Rural Development Programme in 2014 meant it was no longer necessary to have a Glastir Entry agreement in order to access Glastir Advanced. This applied to agreements starting on 1st January 2016. The Glastir scheme records used for selecting survey respondents were correct as of October 2015, and therefore all respondents ought not to have been in only Glastir Advanced. This was confirmed by the scheme agreement data provided by Welsh Government in which there were no farms in Glastir Advanced and not also in Glastir Entry. However, across all survey respondents that reported they were participating in either Glastir Entry or Advanced (*n* 280), 125 claimed to be in only Glastir Entry, 92 in only Glastir Advanced, and 63 in both Entry and Advanced. All farms in Glastir Advanced were therefore assumed to have also been previously in Glastir Entry for a nested analysis of the effects of scheme participation.

Tir Cynnal and Tir Gofal were independent schemes, but land in Tir Gofal was not eligible for Tir Cynnal. This is fully supported by the scheme agreement data provided by Welsh government used for selecting respondents. However, 24 of 323 survey respondents in Tir

Cynnal or Tir Gofal reported that they had previously participated in both schemes. This might reflect an early end to Tir Gofal agreements, that were intended to last for ten years and had a break clause after five years, or management of multiple farms each having different agreement histories. However, for the majority of survey statistics presented here, respondents that claimed to participate in both Tir Cynnal and Tir Gofal were excluded from the analyses.

3. Farm Employment

Hypothesis*: Income generated by agri-environment scheme participation supports employment in the agricultural sector and retention of farm labour.*

The agricultural sector accounts for 4.1% of all employment in Wales. Total labour engaged on farms in Wales was 58,300 in 2015, showing little change from 57,100 in 2005 (**Welsh Government, 2016**). The majority of workers are family (77%) with only small numbers of full-time non-family (6%), part-time non-family (8%) and seasonal or casual workers (9%) (**Wales Rural Observatory, 2010**). Total income from farming in Wales is £201 million in 2014/15 (**Defra; Agriculture in the United Kingdom, 2015**). Annual average farm business income varied from £22,500 and £25,500 for grazing livestock (Less Favoured Area and Lowland, respectively) to £42,000 for dairy farms, but an estimated 19% of farms in Wales had a net farm business income less than zero.

Environmental payments, generally between £1,000 and £10,000 per farm annually (**Farm Business Survey, Wales, 2014/2015**) contribute to total farm income. Environmental payments to farms in Wales average between <1 and 10% of total farm output, and are highest for hill cattle and sheep farms, in comparison to the Single Payment Scheme that accounted for between 6 and 23% of total farm output (**Farm Business Survey, Wales, 2014/15**). Overall, the total direct payments made to farms through Glastir were £37 million in 2015, compared to a total of £208 million under the Single Payment Scheme (**Defra; Agriculture in the United Kingdom, 2015**).

The survey recorded the current total number of persons employed on a farm, and any change that had occurred in the past three years for non-scheme farms, for comparison with any change that was explicitly reported by the farm manager as the result of ending a previous Tir Cynnal or Tir Gofal scheme agreement, or entering a current Glastir scheme agreement. Farms with no current or previous employees (*n* 14) or where the farm manager had retired (*n* 6) were excluded from the analysis.

Table 3.1 Average total number of full and part-time persons employed on surveyed farms, stratified by farm type and size (*n* 601).

	Farm Type		
Farm Size	**DAIRY**	**CS-DA+CS-LOW**	**CS-SDA**
SR1b	1.5 (1 to 2)	1.9 (1.7 to 2.1)	1.8 (1.6 to 2)
SR2	2.1 (1.7 to 2.5)	2.0 (1.8 to 2.2)	1.9 (1.6 to 2.1)
SR3	2.7 (2.3 to 3)	2.2 (1.9 to 2.6)	2.2 (1.9 to 2.4)
SR4	3.2 (2.9 to 3.6)	3.0 (2.6 to 3.3)	2.6 (2.3 to 2.8)
SR5	4.7 (4.2 to 5.3)	2.8 (2 to 3.5)	3.5 (2.7 to 4.4)
ALL	**3.3 (2.9 to 3.6)**	**2.1 (1.9 to 2.2)**	**2.2 (2.1 to 2.4)**

An average of 2.4 persons were found employed per farm in a full or part-time capacity (*n* 579). The number of persons employed increased significantly with farm size and on the DAIRY farm type (*kruskal-wallis*, P<0.01) (**Table 3.3**).

Overall, few survey respondents reported an increase (*n* 20) or a decrease (*n* 19) in the number of persons employed, regardless of scheme participation history. This most likely reflects the importance of family labour on Welsh farms. The low background rate of change meant that it was not possible to discern an effect of scheme participation on employment with any great confidence, although a greater number of farms in the Glastir scheme attributed an increase in employment (*n* 12) than did a decrease in employment (*n* 3) contrary to the farms that were non-scheme or had exited the previous Tir Cynnal or Tir Gofal schemes (**Tables 3.2 to 3.5**).

Table 3.2 Surveyed number of non-scheme farms reporting an increase or a decrease in the total number of persons employed in the past three years, and the frequency (%) of the factors influencing the change (*n* 142).

		Frequency (%) of Factors Influencing Change					
Change	**Farm Count**	**Cost Saving**	**Farm Enlargement**	**Farm Diversification**	**Use of Contractors**	**Grant Payment**	**Other**
Increase	5	0	20	40	20	0	20
Decrease	8	38	0	0	38	13	25

Table 3.3 Surveyed number of farms previously in the Tir Cynnal or Tir Gofal scheme, but not in Glastir, reporting an increase or a decrease in the total number of persons employed as a result of ending the scheme agreement, and the frequency (%) of other factors influencing change (*n* 146).

		Frequency (%) of Factors Influencing Change					
Change	**Farm Count**	**Cost Saving**	**Farm Enlargement**	**Farm Diversification**	**Use of Contractors**	**Grant Payment**	**Other**
Increase	3	33	33	33	33	0	0
Decrease	8	63	0	13	25	38	25

Table 3.4 Surveyed number of farms currently in the Glastir scheme, reporting an increase or a decrease in the total number of persons employed as a result of entering into the scheme agreement, and the frequency (%) of other factors influencing the change (*n* 291).

		Frequency (%) of Factors Influencing Change					
Change	**Farm Count**	**Cost Saving**	**Farm Enlargement**	**Farm Diversification**	**Use of Contractors**	**Grant Payment**	**Other**
Increase	12	8	17	25	17	33	8
Decrease	3	100	33	33	33	33	0

The overall net change in the total number of persons employed, across all surveyed farm types and sizes, was a statistically significant increase of 1.9% (CI +0.5 to +3.8%) for farms entering into any Glastir scheme agreement ($P<0.05$), compared to an insignificant decrease of 0.1% (CI -2.7 to +2.3%) for non-scheme farms and an insignificant decrease of 1.5% (CI -3.1 to +0.3%) for farms exiting a previous Tir Cynnal or Tir Gofal scheme agreement.

A decrease in persons employed was frequently associated with the need for cost savings (58%) or the withdrawal of a grant (26%). Farm diversification was most frequently (30%) associated with an increase in persons employed. Use of contractors was associated with both an increase (25%) and decrease (32%) in persons employed.

There is evidence of a small net increase in farm employment as a result of participation in the Glastir scheme, but the very low number of farms reporting any change means that this result should be treated with considerable caution.

4. Grazing Livestock Number

Hypothesis*: agri-environment scheme field management prescriptions, especially relating to stocking rates and fertiliser application to forage crops, and income generation contribute to changing farm management strategies and a net change in grazing livestock numbers.*

The Glastir agri-environment scheme management agreements include a number of prescriptions that restrict stocking, fertiliser and manuring rates on habitat land. The more popular of the options taken up by farmers have included “grazed permanent pasture with no or very low inputs (No. 15 and 15b)” and “maintenance of woodland fences (No. 40)” to exclude grazing livestock. There is further informal evidence in farmer discussion forums that restrictions on stocking rates were sufficient to discourage scheme participation, and a previous desk-exercise established that achieving sustainable stocking rates on Open Country habitat land defined by **Welsh Government (2012)** had the potential to reduce local sheep numbers by 45% locally and 5% nationally (**Anthony, 2013**). Surveys of changes in practice under the preceding Tir Cynnal and Tir Gofal schemes established that significant reductions in expenditure on fertiliser (**AgraCEAS, 2003; ADAS, 2010**) and absolute quantities of fertiliser used (**Anthony *et al*., 2013**) on supporting grassland had occurred under scheme. Reductions in livestock numbers were also identified (**Anthony *et al*., 2012**) although a large proportion of farmers reported that changes would possibly of definitely have occurred regardless of scheme entry (**ADAS, 2010**).

Changes in stock numbers have a direct effect on pollutant emissions, especially enteric methane emissions from ruminants that presently cannot be controlled by any other means. There is no central record of any changes in stock numbers resulting from the Glastir scheme agreements. This survey therefore sought to establish the extent of change and how this compares to the background rate due to other economic drivers.

The survey asked respondents who have never participated in an agri-environment scheme to report the change in stock numbers in the past three years in order to establish a background rate for comparison, and those who had exited the previous Tir Cynnal or Tir Gofal schemes (but had not entered the Glastir scheme) to report the change in stock that occurred as a result of ending the scheme agreement. Respondents who were participating in the Glastir scheme were asked to report any change in stock numbers that was a result of the current scheme agreement. Change was not necessarily a direct result of a scheme management prescription, and could have a resulted from a change in farm business strategy that took account of the management requirements and income generated by scheme participation.

The analysis excluded respondents that were participating in the Commons, Organic, Woodland or Efficiency elements of the Glastir scheme. The analysis also excluded any farms that introduced or abandoned a grazing livestock enterprise entirely.

Tables 4.1 to **4.3** summarise the percent of farms reporting an increase or decrease in the numbers of grazing livestock and the net percentage change in stock number across all farms.

The background rate of change in stock number (**Table 4.1**) was generally twice that attributed to ending (**Table 4.2**) or entering (**Table 4.3**) a scheme agreement. The percent of non-scheme farms reporting a decrease or increase in stock numbers was in the range 14.6 to 33.3%, in comparison to a range of 2.9 to 19.0% for farms exiting scheme and a range of 0 to 19.6% for farms entering scheme. This allowed us some confidence that the survey respondents did report the effects of changing scheme status rather than the background rate of change.

On those respondent's farms where change had occurred for whatever reason, the overall average increase or decrease in the number of animals was 140 breeding ewes, 32 dairy cows, 14 suckler cows and 47 beef finisher cattle. The average change in stock number represented between 30 and 40% of the typical herd size. There was no significant difference in the average change in stock number between farms reporting an increase or decrease.

When the number of farms reporting no change is taken into account, a net increase of 4.8% in dairy cow numbers in the past three years was calculated for the non-scheme farms, although not statistically significant, and a net decrease of 6.3% in the number of breeding ewes ($P<0.05$). There was no net change in beef suckler cows, and there were too few respondents with beef finisher cattle to determine change with any confidence. These values can be compared to June Agricultural Survey (Wales) reports of a 10% increase in national total dairy cattle and breeding ewe numbers, and a decrease of 4% in beef cattle numbers in the past three years (**Welsh Government, 2013 to 2015**). The discrepancy in direction of change for breeding ewes may reflect changing market conditions during 2016, or irregularities in the June Agricultural Survey results for 2013 that reported a 15% step change in the number of lambs per ewe on farm. The latter may have been due to retention of lambs whilst market prices were depressed, so that more lambs were on farm when the survey took place, or uncertainty in the number of breeding ewes.

For farms having exited the Tir Cynnal or Tir Gofal schemes, there was a statistically significant net increase of 3.7% in dairy cow ($P<0.01$) and a decrease of 5.8% in suckler cow numbers ($P<0.05$). For farms participating in the Glastir scheme there was a statistically significant net decrease of 3.9% in breeding ewe numbers. However, the change was associated only with farms in the Advanced level of the scheme. The net reduction in breeding ewe numbers for these farms was 5.8% (*n* 101; CI 2.6 to 9.7%). There was no difference in the net change of beef suckler or dairy cow numbers between the Entry and Advanced levels of Glastir. The frequency and magnitude of change are similar to those reported by **Anthony *et al.* (2012)** for farms entering the Tir Gofal scheme.

Table 4.1 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, in the previous three years for farms that had never participated in an agri-environment scheme.

Statistic	Sheep (*n* 99)	Beef Suckler (*n* 71)	Beef Finisher (*n* 24)	Dairy (*n* 41)
Stock Decrease	30.3 (21.2 to 39.4)	25.4 (15.5 to 35.2)	16.7 (4.2 to 33.3)	14.6 (4.9 to 26.8)
Stock Increase	15.2 (8.1 to 22.2)	22.5 (12.7 to 32.4)	33.3 (16.7 to 54.2)	29.3 (17.1 to 43.9)
Net Change	-6.3 (-11.4 to -2.2)	-1.6 (-10.1 to 5.7)	16.6 (-4.1 to 49.2)	4.8 (-0.3 to 10.7)

Table 4.2 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 ending a previous Tir Cynnal or Tir Gofal scheme agreement.

Statistic	Sheep (*n* 90)	Beef Suckler (*n* 68)	Beef Finisher (*n* 21)	Dairy (*n* 35)
Stock Decrease	12.2 (5.6 to 20.0)	13.2 (5.9 to 22.1)	19.0 (4.8 to 38.1)	2.9 (0.0 to 8.6)
Stock Increase	6.7 (2.2 to 12.2)	5.9 (1.5 to 11.8)	9.5 (0.0 to 23.8)	14.3 (2.9 to 25.7)
Net Change	-5.8 (-15.2 to 3.9)	-5.8 (-12.6 to -0.6)	-0.2 (-27.9 to 41.6)	3.7 (0.5 to 7.9)

Table 4.3 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.

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

Where an increase in stock number occurred, the factors influencing the decision other than scheme participation most frequently included change in market prices (28%) and availability of land to rent (24%) (**Figure 4.1**). Other factors volunteered by the respondents included change in the availability of staff (3%) and seeking to improve income (7%).

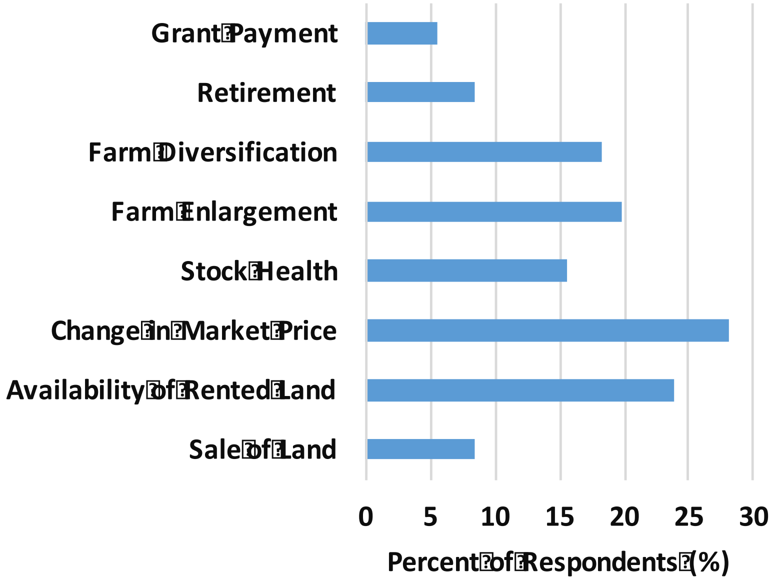

Figure 4.1 Percent of survey respondents citing specific factors influencing the decision to increase grazing livestock numbers.

There is evidence of a net decrease in total breeding ewe numbers on farms participating in the Advanced level of the Glastir scheme. Change occurs on only a proportion of farms in scheme, and is less than background rate of change occurring on non-scheme farms due to other market factors.

5. Fertiliser Rate

Hypothesis: *agri-environment scheme field management prescriptions, especially relating to fertiliser application, and income generation contribute to changing management strategies and can result in net changes in nutrient inputs.*

A key hypothesis in this study was that agri-environment scheme participation would promote and encourage net reductions in the overall use of fertiliser and chemicals through efficiency gains. Under the previous Tir Cynnal and Tir Gofal schemes there were no specific obligations specifying the maximum amount of fertiliser that could be applied. However, as part of the required Farm Resource Management Plan under the Tir Cynnal scheme, Nutrient Management Plans and regular soil analysis was required to help ensure that crop and grass yields were optimised without the use of excessive fertiliser and lime applications (**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**). As a result, it is hypothesised that there would be a net reduction in fertiliser inputs. In addition, under the 'Whole Farm Section', participants in both the Tir Gofal and Tir Cynnal scheme were obliged to retain buffer strips from the base of field boundaries without applying any fertilisers, lime, herbicides or other pesticides (**Welsh Assembly Government, 2005a**), further reducing nutrient inputs. Scheme participation also had to comply with Cross Compliance which prohibited the application of fertilisers, off-farm wastes and other chemicals to land within 1m of a water feature. Subsequent surveys of changes in practice under these preceding schemes established that significant reductions in expenditure on fertiliser (**AgraCEAS, 2003; ADAS, 2010**) and absolute quantities of fertiliser used (**Anthony *et al.,* 2013**) had occurred under scheme.

As part of the 'Whole Farm Code' under the Glastir agri-environment scheme, application of inorganic and organic fertilisers on habitat land was prohibited. Participants were also encouraged to ensure that nutrients from slurry was fully utilised so that less manufactured fertilisers were required, reducing nutrient inputs (**Welsh Assembly Government, 2013**). Under the Glastir scheme management agreements, a number of prescriptions restrict fertiliser and manuring rates on habitat land. The more popular of the options taken up by 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**). The Whole Farm Code requirements were similarly applicable for participants in Glastir Advanced. Under this targeted element of Glastir, certain areas have been identified for actions to improve water quality. Within Priority Areas 1 and 2, Nutrient Management and storage Plans required on farms applying for the Glastir Advanced scheme aimed to prevent over application of slurry and fertilisers and to reduce nutrients leaching into watercourses (**Welsh Assembly Government, 2016**). As a result, it is hypothesised that the Glastir agri-environment scheme would promote and encourage net reductions in the overall use of fertiliser and chemicals and improve practices.

There is no central record of any changes in fertiliser use resulting from the Glastir scheme agreements. This survey therefore sought to establish the extent of change and how this compares to the background rate due to other economic drivers.

Tables 5.1 to **5.3** summarise the percent of farms reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical grassland fields, stratified by farm type.

The percent of non-scheme farms reporting a decrease or increase in the use of manufactured phosphate fertiliser on grassland fields was in the range of 20.5 to 33.3% in comparison to a range of 15.4 to 29.6% for farms exiting the previous schemes and a range of 38.5 to 44.1% for farms entering the Glastir scheme. The difference between the range for participants entering the Glastir scheme and non-scheme farms gives us confidence that the survey respondents did report the effects of changing scheme status rather than the background rate of change.

When the number of farms reporting no change is taken into account, a statistically significant (P<0.05) net decrease of 5.9% in manufactured phosphate fertiliser use on grassland fields for the CS-SDA farm type in the past three years was calculated for the non-scheme farms. A net decrease of 4.9% in phosphate fertiliser use for the CS-DA+CS-LOW farm type and a net decrease of 3.3% for the DAIRY farm type were calculated for the non-scheme farms (P<0.05).

For farms having exited the Tir Cynnal or Tir Gofal schemes there was a statistically significant net decrease of 7% in phosphate fertiliser use on grassland fields for CS-SDA farms and a decrease of 2.9% in fertiliser use on DAIRY farms (P<0.05). A net increase of 3.5% in phosphate fertiliser use on typical grassland fields was calculated for the CS-DA+CS-LOW farm type, although not statistically significant.

For farms participating in the Glastir scheme there was a statistically significant net decrease of 13.7% in the use of manufactured phosphate fertiliser on grassland fields for DAIRY farms, and a net decrease of 9.4% for the CS-DA+CS-LOW farm type (P<0.05). A statistically significant net decrease of 6.5% in the use of phosphate fertiliser on grassland fields was calculated for the CS-SDA farm type (P<0.05).

Table 5.4 summarises the overall percent of farms reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical grassland fields, stratified by history of scheme participation.

The overall percent of non-scheme farms reporting a decrease or increase in the use of manufactured phosphate fertiliser on grassland fields was 23.8% in comparison to a 22.7% for farms exiting the previous schemes and 40.0% for farms entering the Glastir scheme.

When the number of farms reporting no change is taken into account, a statistically significant (P<0.05) net decrease of 4.8% in manufactured phosphate fertiliser use on grassland fields in the past three years was calculated for the non-scheme farms. For farms having exited the Tir Cynnal or Tir Gofal schemes there was a small net decrease of 1.8% in phosphate fertiliser use on grassland fields, although statistically insignificant. For farms participating in the Glastir scheme there was a statistically significant net decrease of 9.4% in the use of phosphate fertiliser on grassland fields (P<0.05).

The net reduction in phosphate fertiliser use on grassland fields for farms participating in the Glastir scheme was approximately twice that attributed to non-scheme farms. There was no net change attributed to farmers exiting the Tir Cynnal or Tir Gofal schemes.

Table 5.1 Percent of survey respondents reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical improved grassland fields, and the net percent change in the use, in the previous three years for farms that had never participated in an agri-environment scheme, stratified by farm type.

Statistic	DAIRY (*n* 18)	CS-DA+CS-LOW (*n* 39)	CS-SDA (*n* 23)
Decrease in the use of manufactured phosphate fertiliser	27.8 (11.0 to 50.0)	12.8 (2.6 to 23.1)	21.7 (4.3 to 39.1)
Increase in the use of manufactured phosphate fertiliser	5.6 (0.0 to 16.7)	7.7 (0.0 to 17.9)	0.0 (0.0 to 0.0)
Net Change	-3.3 (-6.7 to -0.6)	-4.9 (-10.8 to -0.1)	-5.9 (-12.4 to -1.1)

Table 5.2 Percent of survey respondents reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical improved grassland fields, and the net percent change in the use, attributed to ending a previous Tir Cynnal or Tir Gofal scheme agreement, stratified by farm type.

Statistic	DAIRY (*n* 26)	CS-DA+CS-LOW (*n* 27)	CS-SDA (*n* 22)
Decrease in the use of manufactured phosphate fertiliser	15.4 (3.8 to 30.8)	11.1 (0.0 to 22.2)	18.2 (4.5 to 36.4)
Increase in the use of manufactured phosphate fertiliser	0.0 (0.0 to 0.0)	18.5 (3.7 to 33.3)	4.5 (0.0 to 13.6)
Net Change	-2.9 (-6.2 to -0.4)	3.5 (-5.7 to 16.1)	-7.0 (-16.4 to -0.9)

Table 5.3 Percent of survey respondents reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical improved grassland fields, and the net percent change in the use, attributed to a current Glastir scheme agreement, stratified by farm type.

Statistic	DAIRY (*n* 34)	CS-DA+CS-LOW (*n* 49)	CS-SDA (*n* 52)
Decrease in the use of manufactured phosphate fertiliser	41.2 (23.5 to 58.8)	34.7 (22.4 to 46.9)	32.7 (21.2 to 46.2)
Increase in the use of manufactured phosphate fertiliser	2.9 (0.0 to 8.8)	4.1 (0.0 to 10.2)	5.8 (0.0 to 13.5)
Net Change	-13.7 (-21.3 to -6.9)	-9.4 (-15.3 to -4.5)	-6.5 (-12.8 to -0.3)

Table 5.4 Percent of survey respondents reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical improved grassland fields, and the net percent change in the use, summarised across all farm types and stratified by history of scheme participation.

Statistic	Never in scheme (*n* 80)	In previous scheme (*n* 75)	In Glastir (*n* 135)
Decrease in the use of manufactured phosphate fertiliser	18.8 (11.2 to 27.6)	14.7 (6.7 to 22.7)	35.6 (27.4 to 43.7)
Increase in the use of manufactured phosphate fertiliser	5.0 (1.3 to 10.0)	8.0 (2.7 to 14.7)	4.4 (1.5 to 8.1)
Net Change	-4.8 (-8.1 to -2.1)	-1.8 (-6.3 to 3.1)	-9.4 (-13.0 to -5.8)

Where respondents indicated that they do not currently use manufactured phosphate fertiliser on grassland fields (*n* 140), 21.4% specified that they previously used it in the last three years and have therefore recently stopped using it. Of these, only two respondents attributed the decision to stop using phosphate fertiliser to the result of their current Glastir scheme agreement and one respondent ascribed this decision to the result of ending their previous Tir Cynnal or Tir Gofal agreement.

Table 5.5 summarises the overall percent of farms reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical arable fields. The number of respondents using fertiliser on arable fields was small, so the numbers reported on differences stratified by history of scheme participation are summarised across all farm types.

The overall percent of non-scheme farms reporting a decrease or increase in the use of manufactured phosphate fertiliser on arable fields was 2.8% in comparison to 4.8% for farms exiting the previous schemes and 26.6% for farms entering the Glastir scheme.

When the number of farms reporting no change is taken into account, a negligible net decrease of 0.6% in manufactured phosphate fertiliser use on arable fields was calculated for the non-scheme farms. For farms having exited the Tir Cynnal or Tir Gofal schemes there was an insignificant net decrease of 0.5% in phosphate fertiliser use on arable fields. For farms participating in the Glastir scheme a statistically significant ($P<0.05$) net decrease of

7.3% in the use of phosphate fertiliser on arable fields was calculated. This is comparable to that calculated for the reduction on phosphate fertiliser use on grassland fields.

Table 5.5 Percent of survey respondents reporting an increase or decrease in the use of manufactured phosphate fertiliser on typical arable fields, and the net percent change in the use, summarised across all farm types and stratified by history of scheme participation.

Statistic	**Never in scheme (*n* 35)**	**In previous scheme (*n* 21)**	**In Glastir (*n* 64)**
Decrease in the use of manufactured phosphate fertiliser	2.9 (0.0 to 8.6)	4.8 (0.0 to 14.3)	21.9 (12.5 to 32.8)
Increase in the use of manufactured phosphate fertiliser	0.0 (0.0 to 0.0)	0.0 (0.0 to 0.0)	4.7 (0.0 to 10.9)
Net Change	-0.6 (-1.7 to 0.0)	-0.5 (-1.4 to 0.0)	-7.3 (-14.5 to -0.8)

Where respondents indicated that they do not currently use manufactured phosphate fertiliser on arable fields (*n* 42), 21.4% specified that they previously used it in the last three years and have therefore recently stopped using it. Of these, only one respondent attributed the decision to stop using phosphate fertiliser to the result of their current Glastir scheme agreement and one respondent ascribed this decision to the result of ending their previous Tir Cynnal or Tir Gofal agreement. This is comparable to respondents not currently using phosphate fertiliser on grassland fields.

Tables 5.6 to **5.8** summarise the percent of farms reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical grassland fields, stratified by farm type.

The percent of non-scheme farms reporting a decrease or increase in the use of manufactured nitrogen fertiliser on grassland fields was in the range of 31.6 to 39.3% in comparison to a range of 15.4 to 35% for farms exiting the previous schemes and a range of 36.4 to 45.7% for farms entering the Glastir scheme.

When the number of farms reporting no change is taken into account, a statistically significant ($P<0.05$) net decrease of 10.3% in manufactured nitrogen fertiliser use on grassland fields for the CS-SDA farm type in the past three years was calculated for the non-scheme farms. A net decrease of 9.4% in nitrogen fertiliser use on grassland fields for the CS-DA+CS-LOW farm type and a net decrease of 5.4% for the DAIRY farm type were calculated for the non-scheme farms ($P<0.05$). Therefore, across all farm types, there was a significant reduction in the background use of manufactured nitrogen fertiliser.

For farms having exited the Tir Cynnal or Tir Gofal schemes there was a net decrease of 2.3% in nitrogen fertiliser use on grassland fields for the CS-SDA farm type, although not statistically significant. There was a negligible net decrease of 0.2% in nitrogen fertiliser use on typical grassland fields for the CS-DA+CS-LOW farm type and small net increase of 0.8% in fertiliser use on DAIRY farms, although similarly not statistically significant.

For farms participating in the Glastir scheme there was a statistically significant net decrease of 12.2% in the use of manufactured nitrogen fertiliser on typical grassland fields for the CS-DA+CS-LOW farm type, and a net decrease of 8.8% in fertiliser use for DAIRY farms ($P<0.05$). A net decrease of 4.5% in the use of nitrogen fertiliser on grassland fields was calculated for the CS-SDA farm type, although not statistically significant.

Table 5.9 summarises the overall percent of farms reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical grassland fields, stratified by history of scheme participation.

The overall percent of non-scheme farms reporting a decrease or increase in the use of manufactured nitrogen fertiliser on grassland fields was 34.6% in comparison to a 27.4% for farms exiting the previous Tir Cynnal or Tir Gofal schemes and 39.8% for farms entering the Glastir scheme. Farmers are just as likely to increase as decrease their nitrogen fertiliser rates when exiting the previous Tir Cynnal or Tir Gofal scheme, whereas the background trend for the non-scheme farmers, and for those entering the Glastir scheme, show a significant reduction in fertiliser use.

When the number of farms reporting no change is taken into account, a statistically significant ($P<0.05$) net decrease of 8.2% in manufactured nitrogen fertiliser use on grassland fields in the past three years was calculated for the non-scheme farms. For farms having exited the Tir Cynnal or Tir Gofal schemes there was a small net decrease of 0.4% in nitrogen fertiliser use on grassland fields, although statistically insignificant. For farms participating in the Glastir scheme there was a statistically significant net decrease of 8.5% in the use of nitrogen fertiliser on grassland fields ($P<0.05$).

Table 5.6 Percent of survey respondents reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical improved grassland fields, and the net percent change in the use, in the previous three years for farms that had never participated in an agri-environment scheme, stratified by farm type.

Statistic	DAIRY (*n* 28)	CS-DA+CS-LOW (*n* 31)	CS-SDA (*n* 19)
Decrease in the use of manufactured nitrogen fertiliser	35.7 (17.9 to 53.6)	29.0 (16.0 to 45.2)	26.3 (10.4 to 47.4)
Increase in the use of manufactured nitrogen fertiliser	3.6 (0.0 to 10.7)	3.2 (0.0 to 9.7)	5.3 (0.0 to 15.8)
Net Change	-5.4 (-8.6 to -2.3)	-9.4 (-16.6 to -3.1)	-10.3 (-20.5 to -1.3)

Table 5.7 Percent of survey respondents reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical improved grassland fields, and the net percent change in the use, attributed to ending a previous Tir Cynnal or Tir Gofal scheme agreement, stratified by farm type.

Statistic	DAIRY (*n* 26)	CS-DA+CS-LOW (*n* 27)	CS-SDA (*n* 20)
Decrease in the use of manufactured nitrogen fertiliser	3.8 (0.0 to 11.5)	14.8 (3.7 to 29.6)	15.0 (0.0 to 30.0)
Increase in the use of manufactured nitrogen fertiliser	11.5 (0.0 to 26.9)	18.5 (3.7 to 33.3)	20.0 (5.0 to 40.0)
Net Change	0.8 (-0.2 to 2.1)	-0.2 (-9.3 to 10.2)	-2.3 (-10.3 to 4.5)

Table 5.8 Percent of survey respondents reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical improved grassland fields, and the net percent change in the use, attributed to a current Glastir scheme agreement, stratified by farm type.

Statistic	DAIRY (*n* 35)	CS-DA+CS-LOW (*n* 44)	CS-SDA (*n* 44)
Decrease in the use of manufactured nitrogen fertiliser	40.0 (22.6 to 57.1)	36.4 (22.7 to 52.3)	29.5 (18.2 to 43.2)
Increase in the use of manufactured nitrogen fertiliser	5.7 (0.0 to 14.3)	2.3 (0.0 to 6.8)	6.8 (0.0 to 13.6)
Net Change	-8.8 (-15.0 to -3.0)	-12.2 (-17.8 to -6.7)	-4.5 (-11.0 to 2.8)

Table 5.9 Percent of survey respondents reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical improved grassland fields, and the net percent change in the use, summarised across all farm types and stratified by history of scheme participation.

Statistic	Never in scheme (*n* 78)	In previous scheme (*n* 73)	In Glastir (*n* 123)
Decrease in the use of manufactured nitrogen fertiliser	30.8 (20.5 to 41.0)	11.0 (4.1 to 17.8)	35.0 (26.8 to 43.9)
Increase in the use of manufactured nitrogen fertiliser	3.8 (0.0 to 9.0)	16.4 (8.2 to 24.7)	4.9 (1.6 to 9.8)
Net Change	-8.2 (-12.0 to -4.7)	-0.4 (-4.7 to 4.0)	-8.5 (-12.1 to -4.8)

Where respondents indicated that they do not currently use manufactured nitrogen fertiliser on typical improved grassland fields (*n* 156), 12.2% specified that they previously used it in the last three years and have therefore stopped using it. Of these, four respondents attributed the decision to stop using nitrogen fertiliser to the result of their current Glastir agreement and one respondent ascribed this decision to the result of ending their previous Tir Cynnal or Tir Gofal agreement.

Table 5.10 summarises the overall percent of farms reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical arable fields, stratified by history of scheme participation.

The overall percent of non-scheme farms reporting a decrease or increase in the use of manufactured nitrogen fertiliser on arable fields was 13.8% in comparison to 8.3% for farms exiting the previous Tir Cynnal or Tir Gofal schemes and 22.6% for farms entering the Glastir scheme.

When the number of farms reporting no change is taken into account, a statistically significant net decrease of 2.9% in manufactured nitrogen fertiliser use on arable fields was calculated for the non-scheme farms ($P<0.05$). For farms having exited the Tir Cynnal or Tir Gofal schemes there was a small net decrease of 0.8% in nitrogen fertiliser use on arable fields, although not statistically significant. For farms participating in the Glastir scheme a statistically insignificant net decrease of 2.7% in the use of nitrogen fertiliser on arable fields was calculated. In general, the net rate of change for nitrogen fertiliser use on arable fields was much lower than that seen for grassland fields, and as a result, a significant difference cannot be established, particularly for farms exiting the previous schemes and for farms participating in the Glastir scheme.

Table 5.10 Percent of survey respondents reporting an increase or decrease in the use of manufactured nitrogen fertiliser on typical arable fields, and the net percent change in the use, stratified by history of scheme participation.

Statistic	Never in scheme (*n* 29)	In previous scheme (*n* 24)	In Glastir (*n* 62)
Decrease in the use of manufactured nitrogen fertiliser	13.8 (3.4 to 27.6)	0.0 (0.0 to 0.0)	19.4 (9.7 to 29.0)
Increase in the use of manufactured nitrogen fertiliser	0.0 (0.0 to 0.0)	8.3 (0.0 to 20.8)	3.2 (0.0 to 8.1)
Net Change	-2.9 (-1.7 to -0.2)	0.8 (0.0 to 2.1)	-2.7 (-7.1 to 2.1)

Where respondents indicated that they do not currently use manufactured nitrogen fertiliser on typical arable fields (*n* 47), 12.8% specified that they previously used it in the last three years and have therefore stopped using it. Of these, three respondents attributed the decision to stop using nitrogen fertiliser to the result of their current Glastir agreement and no respondents attributed this decision to the result of ending their previous Tir Cynnal or Tir Gofal agreement.

Factors other than explicit scheme management prescriptions can influence the rate of nutrient inputs. Where an increase in fertiliser use occurred, the factors influencing the change other than scheme participation most frequently cited by respondents included change in stock numbers (44%) and being advised by an agronomist (40%).

Where a decrease in fertiliser use occurred for farms participating in the Glastir scheme, the factors influencing the change other than scheme participation most frequently included change in fertiliser cost (55%), being advised by an agronomist (27%) and change in stock numbers (24%) (**Figure 5.1**). Where a decrease in fertiliser use occurred for other farms either never participating in an agri-environment scheme or ending a previous Tir Cynnal or Tir Gofal scheme agreement, the factors influencing the change most frequently included change in fertiliser cost (50%) and change in stock numbers (37%) (**Figure 5.1**). This indicates that the change in fertiliser use is likely to be driven by a change in fertiliser cost and change in stock numbers in addition to requirements to any scheme prescriptions.

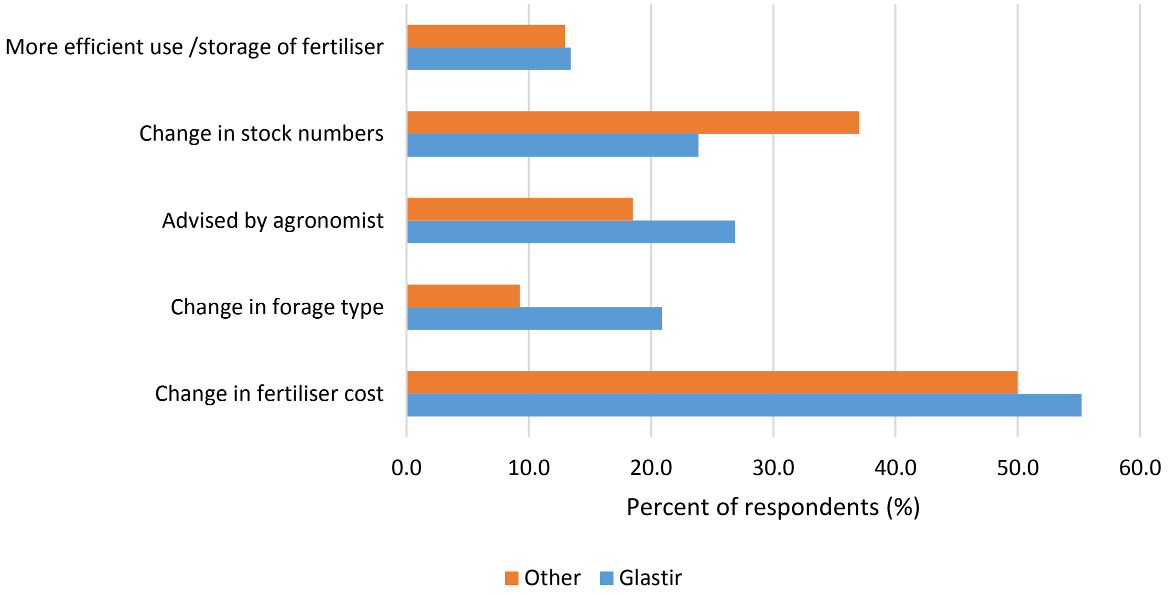

Figure 5.1. Percent of survey respondents citing specific additional factors influencing the change in fertiliser use (*n* 121).

There is evidence of a net decrease in both manufactured phosphate and nitrogen fertiliser use on grassland fields on farms participating in the Glastir scheme. This reduction is comparable in magnitude to the net reduction occurring on non-scheme farms. A high percentage of participants cited fertiliser cost as a factor influencing decisions and therefore the effect of Glastir scheme participation cannot be considered as totally independent and in addition to the non-scheme farms.

6. Nutrient Management

> Hypothesis: *scheme participation supports the completion of individual nutrient management plans and uptake of specific mitigation actions for the correct rate of application to reduce risk of surplus that may contribute to diffuse air and water pollution.*

Farm Nutrient Management Plans aim to improve the efficiency of nutrient use on farms and achieve the environmental benefits of doing so. By matching nutrient inputs to crop demand, nutrient management plans help to optimise yield, minimise nutrient use and reduce losses of nutrients to the environment. It 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

A statutory obligation under the previous Tir Cynnal scheme enforced participants to produce a basic Farm Resource Management Plan and to update it annually in order to maintain acceptable water quality and minimise soil erosion. If farms applied inorganic or organic fertiliser to the agreement land, a Soil Nutrient Management Plan was required under this scheme. Participants were required to estimate 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 (**Welsh Assembly Government, 2005d**).

For the previous Tir Gofal scheme, the completion of a Farm Resource Management Plan, and associated Soil Nutrient Management Plan under the 'Whole Farm Section' was required of farms signing agreements from 2007 (starting in 2008). The majority (95%) of current Tir Gofal agreements were signed before 2008 (**Welsh Assembly Government, 2011**). Accordingly the requirement of Soil Nutrient Plans were not common.

Under the Glastir scheme, there is no specific obligation for participants to produce a Soil Nutrient Management Plan. However, farms are required to maintain field records of all applications of farmyard manures and fertiliser for all the land included in the Glastir Entry contract (**Welsh Assembly Government, 2013**). Under the targeted element of Glastir (Glastir Advanced) certain areas have been identified for actions to improve water quality. Within Priority Areas 1 and 2, Natural Resources Wales commissioned FACTS qualified practitioners to complete Nutrient Management Plans on farms applying for the Glastir Advanced scheme with the aim to prevent over application of slurry and fertilisers and to reduce nutrients leaching into watercourses (**Welsh Assembly Government, 2016**).

Therefore scheme participation, particularly Tir Cynnal and Glastir Advanced (priority areas) was hypothesised to result in a greater awareness of good practice for the rate and timing of fertiliser applications, and accounting for the nutrient status of soils and value of manures. A key element of this management plan is to fertilise to the crop's requirement, so it was hypothesised that scheme participation would have a positive effect on fertiliser management actions being undertaken to achieve correct rate of application, for example, calibration of fertiliser spreaders and delaying application to avoid spreading to wet or frozen ground.

This survey established the percentage of farms having completed a Soil Nutrient Management Plan as a general indication of good practice. Information on specific soil nutrient management actions carried out by farmers was then collected to establish the rate of which good fertiliser practice was being put into practice.

Figure 6.1 and Table 6.1 summarise the percent of respondents presently using phosphate and nitrogen fertiliser anywhere on farm stratified by farm type. The percent of farms using both types of fertiliser did not vary significantly with scheme level (*Kruskal Wallis test,* P>0.10). The percent of respondents presently using fertiliser anywhere on their farm were significantly lower for CS farms in comparison to the DAIRY farm type. The percent of cattle and sheep farms using manufactured phosphate fertiliser was 13.7% lower, whereas the percent using manufactured nitrogen fertiliser was 32.9% lower (*generalised linear model*, P<0.01).

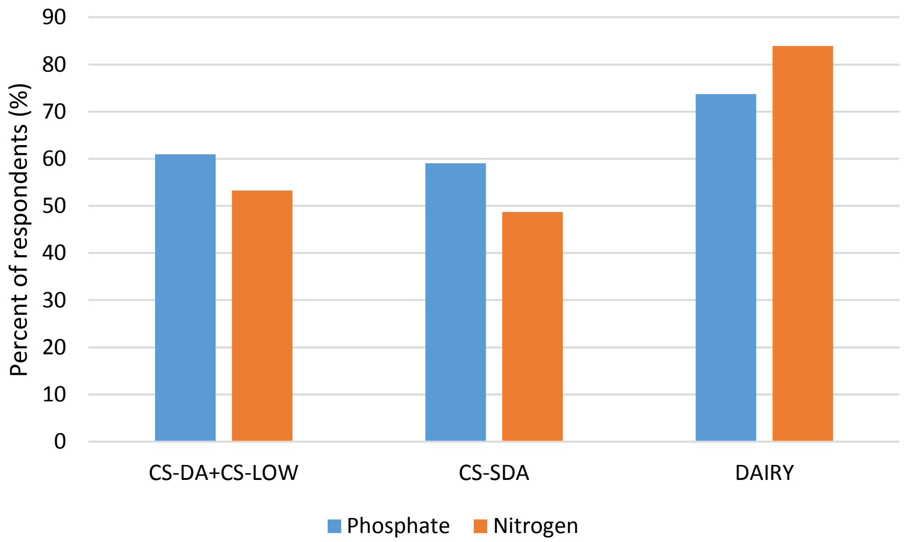

Figure 6.1. Percent of respondents presently using manufactured phosphate and nitrogen fertiliser anywhere on farm, stratified by farm type (*n* 508).

Table 6.1. Percent of respondents presently using manufactured phosphate fertiliser anywhere on farm (*n* 508).

Farm Type	Percent using manufactured phosphate fertiliser	Percent using manufactured nitrogen fertiliser
CS-DA+CS-LOW	59.1 (52.3 to 66.3)	53.3 (46.2 to 60.4)
CS-SDA	60.9 (54.3 to 67.5)	48.7 (42.0 to 56.0)
DAIRY	73.7 (66.1 to 81.4)	83.9 (77.1 to 89.8)

Table 6.2 summarises the average percent of farms completing a soil nutrient management plan stratified by farm type and history of scheme participation. An overall average of 55.8% of farms had completed a soil nutrient management plan. There was a significant (P<0.05) effect of farm type, and history of scheme participation with implementation higher on the DAIRY relative to the CS farms, and lower on farms that are not and have never been in scheme at all. The majority (60.4%) of soil nutrient plans were completed by the farmer or land manager.

Table 6.2. Average percent of farms completing a soil nutrient management plan stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	55.9 (38.2 to 70.6)	40.4 (27.6 to 53.2)	25.0 (9.4 to 40.6)
TC or TG	None	74.2 (58.1 to 87.1)	58.3 (41.7 to 75.0)	58.1 (38.7 to 74.2)
None	GE or GA	94.4 (83.3 to 100.0)	60.0 (43.3 to 76.7)	38.2 (23.5 to 55.9)
TC or TG	GE or GA	81.8 (63.6 to 95.5)	58.1 (41.9 to 74.2)	58.8 (44.1 to 76.5)

The uptake of a soil nutrient management plan was significantly lower on CS farms with a marginal effect of 26.4% (*generalised linear model,* P<0.01) (**Table 6.3**). Participation in the Glastir scheme and the previous Tir Cynnal scheme were associated with a significantly higher percent of farmers completing a soil nutrient management plan. The calculated marginal effect was 13.2 and 28.3% respectively (*generalised linear model,* P 0.01 and <0.01) (**Table 6.3**).

Table 6.3. Coefficients and marginal effects of binomial model fitted to the proportion of respondents completing a soil nutrient management plan (*n* 380).

<table>
<tr><th colspan="7">Binomial Model Coefficients and Marginal Effects</th></tr>
<tr><td rowspan="11">Completed a soil nutrient management plan</td><td rowspan="11"></td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>0.5370</td><td>0.2433</td><td>2.207</td><td>0.03</td></tr>
<tr><td>Is_CS</td><td>-1.1644</td><td>0.2628</td><td>-4.431</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>1.2558</td><td>0.2641</td><td>4.754</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.5434</td><td>0.2243</td><td>2.423</td><td>0.02</td></tr>
<tr><td>AIC:</td><td>480.1</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS</td><td>-0.264494</td><td>0.052977</td><td>-4.9926</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.283051</td><td>0.052006</td><td>5.4426</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.131762</td><td>0.053497</td><td>2.4630</td><td>0.01</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Figure 6.2 and Table 6.4 summarise the percent of respondents using different approaches to assess the nutrient requirement of crops and grassland, stratified by farm type. The percentage of farmers using professional advice or RB209, PLANET or similar software to assess the nutrient requirement of crops and grassland was 42.4 and 7.4% respectively. However, the majority of farmers (75.3%) assessed the nutrient requirement of crops and grassland using own knowledge or experience. Of these, 47.2% solely rely on own knowledge or experience when assessing the nutrient requirement of crops and grassland.

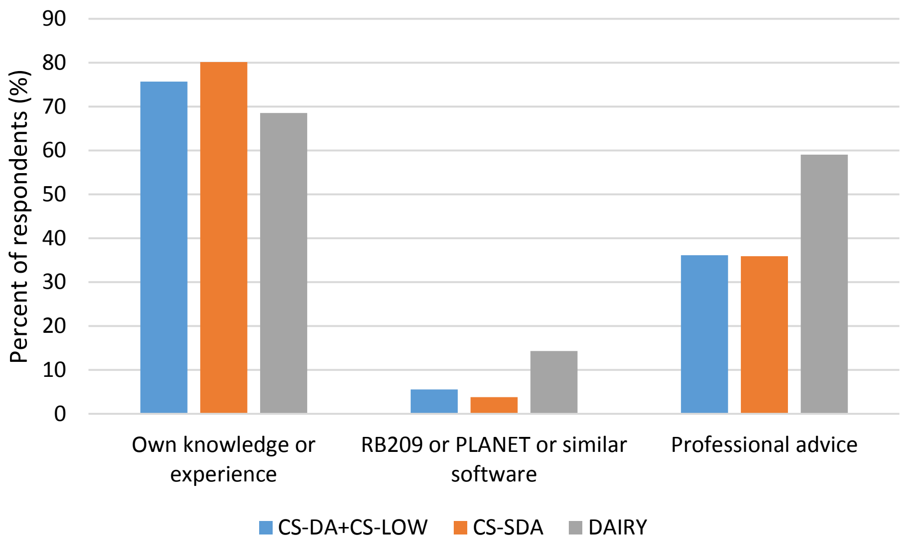

Figure 6.2. Percent of respondents undertaking different actions to assess the nutrient requirement of crops and grassland, stratified by farm type (*n* 380).

Table 6.4. Percent of respondents assessing the nutrient requirement of crops and grassland using different activities (*n* 380).

Activity to assess nutrient requirement of crops and grassland	Percent of respondents
Own knowledge or experience	75.3 (10.8 to 79.7)
RB209 or PLANET or similar software	7.4 (4.7 to 10.3)
Professional advice	42.4 (37.6 to 47.9)

Statistical modelling found that there was a significant effect of farm type on the percentage of respondents using RB209, PLANET or similar software, and professional advice. The percentage of respondents undertaking these specific approaches to assess the nutrient requirement of crops and grassland were significantly lower on CS farms in comparison to the DAIRY farm type. The calculated marginal effects were 8.9 and 23% respectively (*generalised linear model,* P 0.01 and <0.01) (**Table 6.5**). Participation in the previous Tir Cynnal scheme was associated with a significantly higher percent of farmers using RB209, PLANET or similar software in comparison to the background rate of non-scheme farms. The calculated marginal effect was 7.4% (*generalised linear model,* P 0.03) (**Table 6.5**).

Table 6.5. Coefficients and marginal effects of binomial model fitted to the proportion of respondents taking specific activities to assess the nutrient requirement of crops and grassland (*n* 380).

Binomial Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-2.1792	0.3367	-6.472	<0.01
		Is_CS	-1.2287	0.4034	-3.045	<0.01
		Is_TC	1.0588	0.4041	2.620	0.02
RB209 or PLANET or similar software		AIC:	190.17			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.089350	0.034805	-2.5672	0.01
		Is_TC	0.073766	0.033050	2.2319	0.03
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.3659	0.1985	1.844	0.07
		Is_CS	-0.9413	0.2349	-4.008	<0.01
Professional advice		AIC:	505.48			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.230476	0.056043	-4.1125	<0.01

Table 6.6 summarises the average total number of fertiliser management actions taken in the last three years and the percent of respondents taking specific action. There was a significant (P<0.01) effect of farm type with the average number of actions increasing on the DAIRY relative to the CS farms. Only 10% of respondents did not take any fertiliser management actions in the last three years. The action most frequently implemented by the DAIRY farm type was testing soil nutrient status (81.9%), whereas the action most frequently implemented by the CS farms was delaying application to avoid spreading to wet or frozen ground (67.4%).

Statistical modelling found that the total number of fertiliser management actions were significantly lower on CS farms in comparison to the DAIRY farm type (*generalised linear model,* P<0.01). In general, CS farms carried out 0.98 fewer total actions (**Table 6.7**). The percent of respondents carrying out fertiliser management actions involving the calibration of fertiliser spreaders, testing of soil nutrient status, using a fertiliser recommended system and the increased use of straight rather than compound fertiliser were significantly lower on CS farms in comparison to the DAIRY farm type. The calculated marginal effect was in the range of 17.3 and 27.7% (*generalised linear model,* P<0.01) (**Table 6.7**).

The percent of respondents delaying application to avoid spreading to wet or frozen ground were significantly lower for the CS-SDA farm type in comparison to the DAIRY farms, with a marginal effect of 16.3% (*generalised linear model,* P 0.01) (**Table 6.7**).

Participation in the Glastir scheme was associated with a significantly higher total number of fertiliser management actions (*generalised linear model,* P 0.02). Respondents in the Glastir scheme carried out 0.39 more total actions (**Table 6.7**). A significantly higher percentage of respondents participating in the Glastir scheme calibrated fertiliser spreaders, tested soil nutrient status and delayed application to avoid spreading on wet or frozen ground. The latter of these management actions directly relates to the Glastir scheme management prescription “do not apply manures or dirty water when soil is waterlogged or frozen hard”. The calculated marginal effect was in the range of 11.9 and 13.5% (**Table 6.7**).

Participation in the previous Tir Cynnal scheme was associated with a significantly higher total number of fertiliser management actions (*generalised linear model,* P<0.01). Respondents in the Tir Cynnal scheme carried out 0.55 more total actions (**Table 6.7**). Participation in the Tir Cynnal scheme was associated with a significantly higher percentage of respondents calibrating fertiliser spreaders, testing soil nutrient status and using a fertiliser recommended system. The calculated marginal effect was in the range of 12.7 and 14.4% (**Table 6.7**). These results indicate a legacy of best practice from the previous Tir Cynnal scheme.

Table 6.6. Average count of all fertiliser management actions taken in the last three years, and the percent of farms taking action, stratified by farm type (*n* 380).

	DAIRY	**CS-DA+CS-LOW**	**CS-SDA**
Count of all actions (n)	3.3 (3.1 to 3.6)	2.4 (2.2 to 2.7)	2.3 (2.0 to 2.5)
Calibration of the fertiliser spreader (%)	74.3 (65.7 to 81.9)	52.1 (43.8 to 59.7)	43.5 (34.4 to 52.7)
Testing of soil nutrient status (%)	81.9 (74.3 to 88.6)	59.0 (51.4 to 66.7)	61.1 (52.7 to 68.7)
Use a fertiliser recommendation system (%)	57.1 (47.6 to 66.7)	41.0 (33.3 to 48.6)	38.9 (30.5 to 47.3)
Increased use of straight rather than compound fertiliser (%)	40.0 (30.5 to 50.5)	17.4 (11.1 to 23.6)	24.4 (17.6 to 32.1)
Delayed application to avoid spreading to wet or frozen ground (%)	78.1 (69.5 to 85.7)	73.6 (66.6 to 80.6)	61.1 (51.9 to 69.5)

Table 6.7. Coefficients and marginal effects of poisson and binomial models fitted to the total count of fertiliser management actions taken in the last three years, and the proportion of respondents taking specific actions (*n* 380).

<table>
<tr><th colspan="6">Poisson Model Coefficients and Marginal Effects</th></tr>
<tr><td rowspan="13">Total Count of Actions</td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>1.07561</td><td>0.06372</td><td>16.881</td><td><0.01</td></tr>
<tr><td>Is_CS</td><td>-0.34980</td><td>0.06668</td><td>-5.246</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.20338</td><td>0.06772</td><td>3.003</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.15118</td><td>0.06363</td><td>2.376</td><td>0.02</td></tr>
<tr><td>AIC:</td><td>1353.1</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS</td><td>-0.97959</td><td>0.20082</td><td>-4.8781</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.54905</td><td>0.19088</td><td>2.8764</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.39315</td><td>0.16671</td><td>2.3583</td><td>0.02</td></tr>
<tr><th colspan="6">Binomial Model Coefficients and Marginal Effects</th></tr>
<tr><td rowspan="10">Calibration of the fertiliser spreader</td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Intercept)</td><td>0.7383</td><td>0.2434</td><td>3.033</td><td><0.01</td></tr>
<tr><td>Is_CS</td><td>-1.2130</td><td>0.2591</td><td>-4.681</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.5279</td><td>0.2442</td><td>2.162</td><td>0.03</td></tr>
<tr><td>Is_GEGA</td><td>0.5277</td><td>0.2189</td><td>2.411</td><td>0.02</td></tr>
<tr><td>AIC:</td><td>497.77</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS</td><td>-0.277210</td><td>0.052274</td><td>-5.3030</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.127153</td><td>0.056968</td><td>2.2320</td><td>0.03</td></tr>
<tr><td>Is_GEGA</td><td>0.128823</td><td>0.052629</td><td>2.4478</td><td>0.01</td></tr>
<tr><td rowspan="10">Testing of soil nutrient status</td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>1.1513</td><td>0.2712</td><td>4.246</td><td><0.01</td></tr>
<tr><td>Is_CS</td><td>-1.1790</td><td>0.2873</td><td>-4.104</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.7047</td><td>0.2673</td><td>2.636</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.5508</td><td>0.2303</td><td>2.391</td><td>0.02</td></tr>
<tr><td>AIC:</td><td>464.19</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS</td><td>-0.229012</td><td>0.047105</td><td>-4.8618</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.144397</td><td>0.050402</td><td>2.8649</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.118691</td><td>0.048549</td><td>2.4448</td><td>0.01</td></tr>
</table>

Table 6.7 ***cont.*** Coefficients and marginal effects of poisson and binomial models fitted to the total count of fertiliser management actions taken in the last three years, and the proportion of respondents taking specific actions (*n* 380).

<table>
<tr><th colspan="7">Binomial Model Coefficients and Marginal Effects</th></tr>
<tr><td rowspan="9">Use a fertiliser recommended system</td><td rowspan="9"></td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>0.1320</td><td>0.2080</td><td>0.635</td><td>>0.10</td></tr>
<tr><td>Is_CS</td><td>-0.6989</td><td>0.2344</td><td>-2.982</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.5654</td><td>0.2334</td><td>2.422</td><td>0.02</td></tr>
<tr><td>AIC:</td><td>513.66</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS</td><td>-0.172821</td><td>0.057052</td><td>-3.0292</td><td><0.01</td></tr>
<tr><td>Is_TC</td><td>0.140132</td><td>0.057418</td><td>2.4406</td><td>0.01</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="6">Increased use of straight rather than compound fertiliser</td><td rowspan="6"></td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>-0.4055</td><td>0.1992</td><td>-2.035</td><td>0.04</td></tr>
<tr><td>Is_CS</td><td>-0.9360</td><td>0.2486</td><td>3.765</td><td><0.01</td></tr>
<tr><td>AIC:</td><td>426.01</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS</td><td>-0.192727</td><td>0.053696</td><td>-3.5893</td><td><0.01</td></tr>
<tr><td rowspan="9">Delayed application to avoid spreading to wet or frozen ground</td><td rowspan="9"></td><td>Model Coefficient</td><td>Estimate</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>(Intercept)</td><td>0.8823</td><td>0.1675</td><td>5.266</td><td><0.01</td></tr>
<tr><td>Is_CS-SDA</td><td>-0.7666</td><td>0.2378</td><td>-3.224</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.6680</td><td>0.2394</td><td>2.791</td><td><0.01</td></tr>
<tr><td>AIC:</td><td>450.34</td><td></td><td></td><td></td></tr>
<tr><td>Marginal Effect</td><td>dF/dx</td><td>Std.Error</td><td>Z Value</td><td>Pr(>|z|)</td></tr>
<tr><td>Is_CS-SDA</td><td>-0.163083</td><td>0.051612</td><td>-3.1598</td><td><0.01</td></tr>
<tr><td>Is_GEGA</td><td>0.133700</td><td>0.046329</td><td>2.8859</td><td><0.01</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Tables 6.8 to **6.13** summarise the count of fertiliser management actions and uptake of specific actions by farm type and history of scheme participation. The results indicate that the contrast between DAIRY and CS farms is larger than the uplift caused by scheme participation.

Table 6.8. Average count of all fertiliser management actions taken in the last three years, stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	3.1 (2.6 to 3.5)	2.1 (1.7 to 2.5)	2.0 (1.4 to 2.5)
TC or TG	None	3.2 (2.7 to 3.6)	2.3 (1.8 to 2.8)	2.5 (1.9 to 3.0)
None	GE or GA	3.6 (2.9 to 4.1)	2.4 (1.8 to 2.9)	2.1 (1.6 to 2.5)
TC or TG	GE or GA	3.7 (3.4 to 4.0)	3.1 (2.7 to 3.5)	2.7 (2.1 to 3.1)

Table 6.9. Average percent of farms calibrating fertiliser spreaders, stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	**None**	**73.5 (58.8 to 85.3)**	**40.4 (25.5 to 53.2)**	**37.5 (21.9 to 56.3)**
TC or TG	**None**	**67.7 (51.6 to 83.9)**	**47.2 (30.6 to 63.9)**	**41.9 (25.8 to 61.3)**
None	**GE or GA**	**83.3 (66.7 to 100.0)**	**53.3 (36.7 to 70.0)**	**35.3 (20.6 to 52.9)**
TC or TG	**GE or GA**	**77.3 (59.1 to 90.9)**	**74.2 (58.1 to 87.1)**	**58.8 (41.2 to 73.5)**

Table 6.10. Average percent of farms testing soil nutrient status, stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	70.6 (52.9 to 85.3)	46.8 (34.0 to 59.6)	53.1 (37.5 to 71.9)
TC or TG	None	83.9 (71.0 to 96.8)	61.1 (44.4 to 77.8)	61.3 (45.2 to 77.4)
None	GE or GA	83.3 (61.1 to 100.0)	56.7 (40.0 to 76.7)	58.8 (41.2 to 76.5)
TC or TG	GE or GA	95.5 (86.4 to 100.0)	77.4 (61.3 to 90.3)	70.6 (55.9 to 85.3)

Table 6.11. Average percent of farms using a fertiliser recommendation system, stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	58.8 (41.2 to 76.5)	34.0 (21.3 to 46.8)	31.3 (15.6 to 47.0)
TC or TG	None	58.1 (38.7 to 74.2)	36.1 (22.2 to 52.8)	58.1 (41.9 to 74.2)
None	GE or GA	50.0 (27.8 to 72.2)	40.0 (23.3 to 56.7)	29.4 (14.7 to 44.1)
TC or TG	GE or GA	59.1 (40.9 to 77.3)	58.1 (38.7 to 74.2)	38.2 (23.5 to 55.9)

Table 6.12. Average percent of farms increasing use of straight rather than compound fertiliser, stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	38.2 (23.5 to 53.0)	12.8 (4.3 to 23.4)	25.0 (9.4 to 40.6)
TC or TG	None	35.5 (19.4 to 51.6)	19.4 (5.6 to 33.3)	25.8 (9.7 to 41.9)
None	GE or GA	38.9 (16.7 to 61.1)	16.7 (6.7 to 33.3)	14.7 (2.9 to 26.5)
TC or TG	GE or GA	50.0 (27.3 to 68.3)	22.6 (9.7 to 38.7)	32.4 (17.6 to 47.1)

Table 6.13. Average percent of farms delaying application to avoid spreading to wet or frozen ground, stratified by farm type and history of scheme participation (*n* 380).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	64.7 (47.1 to 79.4)	76.6 (63.8 to 87.2)	50.0 (34.4 to 68.8)
TC or TG	None	71.0 (54.8 to 84.0)	66.7 (50.0 to 80.6)	58.1 (38.7 to 74.2)
None	GE or GA	100.0 (100.0 to 100.0)	70.0 (53.3 to 86.7)	67.6 (52.9 to 82.4)
TC or TG	GE or GA	90.9 (77.3 to 100.0)	80.6 (67.7 to 93.5)	67.6 (50.0 to 82.4)

There is evidence that participants in the Glastir scheme are more likely to have completed a soil nutrient management plan and are more likely to specifically carry out actions involving the calibration of fertiliser spreaders, testing soil nutrient status and delaying application to avoid spreading to wet or frozen ground. These actions can be related to scheme requirements.

The effect of participation in Glastir is either less than or similar to a legacy of previous participation in the Tir Cynnal scheme. However, there is a high level of uptake already, so changes are small compared to the background rate.

The increased uptake of specific management actions that have directly been associated with scheme participation may actually be a consequence of the completion of a Nutrient Management Plan. Participation in a scheme may result in an enhanced completion rate of Nutrient Management Plans. Establishing whether there is a direct effect of scheme on the update of management actions, or an indirect effect of a higher completion rate of Nutrient Management Plans will be analysed further and reported upon in the third report.

7. Manure Management

> Hypothesis: *scheme participation supports the completion of individual manure management plans and uptake of specific mitigation actions for the correct rate of application to reduce risk of surplus that may contribute to diffuse air and water pollution.*

The method of manure management (as slurry or solid farm yard manure) and timing of spreading are major factors impacting on pollutant emissions to both air and water. Farm Manure Management Plans 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 spreading practices. A Manure Management Plan helps farmers identify when, where and at what rate to spread manures and to assess whether they have enough storage or useable spreading area.

A statutory requirement under the previous Tir Cynnal scheme enforced participants to produce a Farm Resource Management Plan and to update it annually. If farms produced, stored or disposed of slurry, farmyard manure or other organic waste on the agreement land, a Manure Management Plan was required under this scheme. Participants were required to estimate the volumes of slurry and dirty water produced, and the requirements of 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**). A Manure Management Plan was also a statutory requirement for participants in the previous Tir Gofal scheme, but only for new applicants to the scheme from 2007. As stated in section 6, the majority (95%) of Tir Gofal agreements were signed before 2008 (**Welsh Assembly Government, 2011**) indicating that the requirement of Manure Management Plans were not common.

Under the Glastir Entry scheme, there is no specific obligation for participants to produce a Manure Management Plan. However as part of the ‘Whole Farm Code’, farms are required to maintain field records of all applications of farm yard manures, slurry, sludge and other organic wastes (**Welsh Assembly Government, 2013**). Other scheme requirements enforce farmers to adhere to specific spreading practices and management actions, for example, storage prohibition of manure, silage or other farm wastes on habitat land, flood risk area or within 10 metres of any watercourse and the prevention of apply livestock manures and dirty water when the soil is waterlogged or frozen hard. These Whole Farm Code requirements were similarly applicable for participants in Glastir Advanced where participants were required to complete a manure storage plan and risk assessment to identify the risk of point sources on farm associated with manure management. Within Priority Areas 1 and 2 under this targeted element of Glastir, farmers are required to complete a Manure Management Plan to prevent the over application of manure, slurry, dirty water and other organic wastes and reduce diffuse water pollution (**Welsh Assembly Government, 2015**). Therefore scheme participation, particularly Tir Cynnal and Glastir Advanced (priority areas) was hypothesised to result in greater awareness of the seasonal and spatial risk factors affecting runoff and the nutrient value of manures.

This survey established the percentage of farms having completed a Manure Management Plan as a general indication of good practice. Information on specific manure management actions carried out by farmers was then collected to establish the rate of which good manure storage and spreading practice was being put into practice.

Table 7.1 summarises the percent of farms completing a manure management plan stratified by farm type and history of scheme participation. An overall average of 74.9% of farms had completed a manure management plan. There was a significant (P<0.01) effect of farm type, and history of scheme participation with implementation higher on the DAIRY relative to the CS farms, and lower on farms that are not and have never been in scheme at all. The majority (76.2%) of manure management plans were completed by the farmer or land manager. The percent of farmers completing management plans themselves did not vary significantly with scheme level (*Kruskal Wallis test*, P>0.10). The percent of farmers or land managers completing manure management plans themselves were significantly lower on DAIRY farms (67%) in comparison to the CS farms (P<0.01).

Table 7.1. Percent of farms completing a manure management plan stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	82.9 (70.7 to 92.7)	61.0 (47.5 to 74.6)	50.0 (37.0 to 63.0)
TC or TG	None	91.4 (80.0 to 100.0)	74.1 (61.1 to 85.2)	68.9 (55.6 to 82.2)
None	GE or GA	100.0 (100.0 to 100.0)	75.8 (60.6 to 90.9)	66.0 (53.2 to 78.7)
TC or TG	GE or GA	91.3 (78.3 to 100.0)	83.7 (72.1 to 93.0)	85.7 (75.5 to 93.9)

The effect of farm type and history of scheme participation was highlighted during statistical modelling which found that the percentage of respondents completing a manure management plan were significantly lower on CS farms in comparison to the DAIRY farm type, with a calculated marginal effect of 20.3% (*generalised linear model,* P<0.01) (**Table 7.2**). Participation in the Glastir scheme and the previous Tir Cynnal scheme were associated with a significantly higher percent of farmers completing a manure management plan. The calculated marginal effect was 11.9 and 16.7% respectively (*generalised linear model,* P<0.01) (**Table 7.2**).

Table 7.2. Coefficients and marginal effects of binomial model fitted to the proportion of respondents completing a manure management plan (*n* 494).

Binomial Model Coefficients and Marginal Effects						
		Model Coefficient	Estimate	Std.Error	Z Value	Pr(>|z|)
		(Intercept)	1.7676	0.3145	5.621	<0.01
		Is_CS	-1.4801	0.3317	-4.462	<0.01
		Is_TC	1.1197	0.2841	3.941	<0.01
Completed a manure management plan		Is_GEGA	0.7142	0.2277	3.136	<0.01
		AIC:	514.4			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.202541	0.033612	-6.0259	<0.01
		Is_TC	0.166772	0.035292	4.7255	<0.01
		Is_GEGA	0.119124	0.036542	3.2599	<0.01

Figure 7.1 and **Table 7.3** summarise the percentage of animal manure managed as slurry, stratified by farm type. The percent of manure managed as slurry was significantly higher on DAIRY farms in comparison to the CS farms (P<0.01). Overall, it was calculated that 71.2% of manure on DAIRY farms was managed as slurry, and only 14.8% on CS farms.

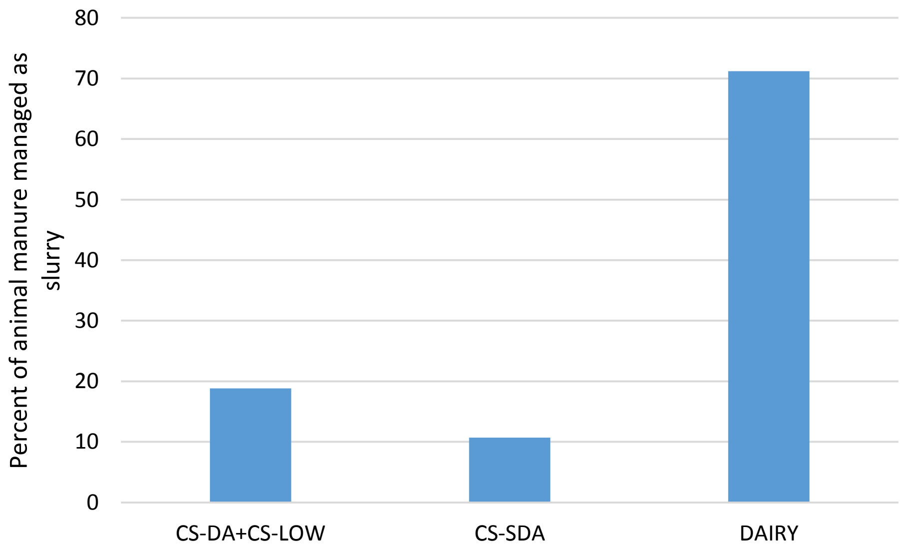

Figure 7.1. Percent of animal manure managed as slurry, stratified by farm type (*n* 494).

Table 7.3. Percent of animal manure managed as slurry, stratified by farm type (*n* 494).

Farm type	Percent
CS-DA+CS-LOW	18.8 (14.5 to 23.2)
CS-SDA	10.7 (7.3 to 14.1)
DAIRY	71.2 (66.8 to 75.3)

Figure 7.2 and Table 7.4 summarise the percent of respondents presently using different approaches to assess the nutrient value of spread manures, stratified by farm type. The percentage of farmers using professional advice or manure testing, and standard values such as RB209 to assess the nutrient value of spread manures was 19.4 and 11.1% respectively. However, the majority of farmers (72.5%) assessed the nutrient value of spreads manures using own knowledge and experience, whereas 20% of farms did not assess at all. Of these, 50.2% solely rely on own knowledge or experience when assessing the nutrient value of spread manures.

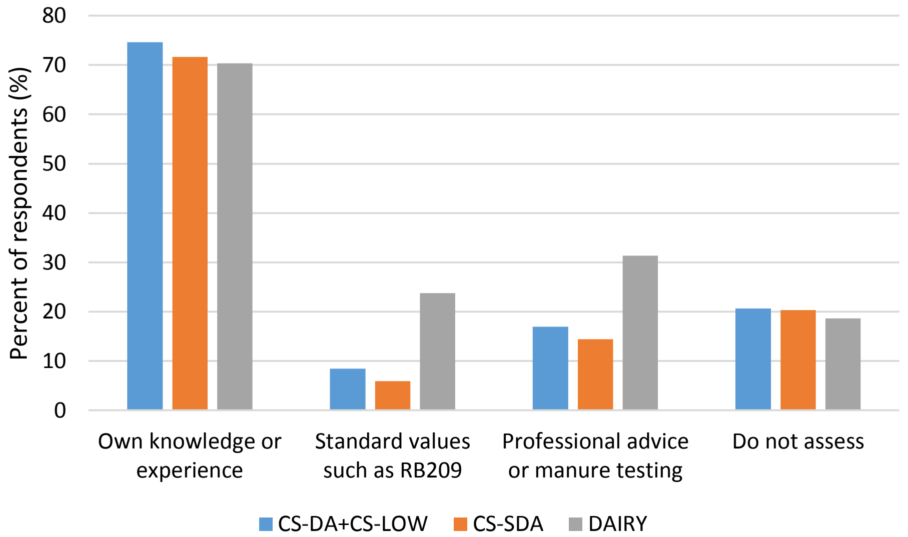

Figure 7.2. Percent of respondents using different actions to assess the nutrient value of spread manures, stratified by farm type (*n* 494).

Table 7.4. Percent of respondents assessing the nutrient value of spread manures using different approaches (*n* 494).

Action to assess nutrient value of spread manures	Percent of respondents
Own knowledge or experience	72.5 (68.6 to 76.3)
Standard values such as RB209	11.1 (8.3 to 14.0)
Professional advice or manure testing	19.4 (16.4 to 22.9)
Do not assess	20.0 (16.6 to 23.9)

Statistical modelling found that there was a significant effect of farm type on the percentage of respondents using standard values such as RB209 and professional advice to assess the value of spread manures. The percentage of respondents undertaking these specific actions to assess the nutrient requirement of crops and grassland were significantly lower on CS farms in comparison to the DAIRY farm type. The calculated marginal effects were 16.5 and 16.2% respectively (*generalised linear model,* P<0.01) (**Table 7.5**). Participation in the previous Tir Cynnal scheme was associated with a higher percent of farmers using professional advice in comparison with the background rate of non-scheme farms. The calculated marginal effect was 9.4% (*generalised linear model,* P 0.02) (**Table 7.5**).

Table 7.5. Coefficients and marginal effects of binomial model fitted to the proportion of respondents taking specific actions to assess the nutrient value of spread manures (*n* 494).

Binomial Model Coefficients and Marginal Effects						
Standard values such as RB209		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.1676	0.2164	-5.396	<0.01
		Is_CS	-1.3916	0.2945	-4.725	<0.01
		AIC:	327.55			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.165480	0.041364	-4.0005	<0.01
Professional advice		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.9426	0.2122	-4.443	<0.01
		Is_CS	-0.9337	0.2465	-3.788	<0.01
		Is_TC	0.5825	0.2446	2.382	0.02
		AIC:	474.0			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.161844	0.046992	-3.4441	<0.01
		Is_TC	0.094585	0.042184	2.2422	0.02

Table 7.6 summaries the average total number of manure management actions taken in the last three years and the percent of respondents taking specific action. There was a significant (P<0.01) effect of farm type with the average number of actions increasing on the DAIRY relative to the CS farms. The percentage of respondents not taking any manure management actions in the last three years (26.1%) was higher than that calculated for the fertiliser management actions. The action most frequently implemented by the DAIRY farm type was separating ‘dirty’ yard water from runoff from clean concrete and roofs (62.7%), whereas the action most frequently implemented by the CS farms was increasing the proportion of manures spread during the spring or growing season (34%).

Statistical modelling established that the total number of manure management actions were significantly lower on CS farms in comparison to the DAIRY farm type (*generalised linear model,* P<0.01). In general, CS farms carried out 1.72 fewer total actions (**Table 7.7**). The percent of respondents carrying out specific manure management actions in general were significantly lower on CS farms in comparison to the DAIRY farm type. However, this is not the case for the manure management action involving covering manure heaps, which did not show any farm type effect. The prevalence of moving manure heaps away from watercourses as a manure management action did not differ between farm types or with history of scheme participation

The percent of respondents reducing water usage for watering or cleaning livestock and buildings was significantly lower for the CS-SDA farm type in comparison to DAIRY farms, with a marginal effect of 13.9% (*generalised linear model,* P<0.01) (**Table 7.7**).

Participation in the Glastir scheme was associated with a significantly higher total number of manure management actions (*generalised linear model,* P<0.01). Respondents in the Glastir scheme carried out 0.51 more total actions (**Table 7.7**). Participation in the Glastir scheme was also associated with a significantly higher percentage of respondents increasing the size of their slurry store, covering manure heaps and calibrating manure spreaders in comparison to the background rate of non-scheme farms. The calculated marginal effect was in the range of 6.8 and 8% (**Table 7.7**).

Participation in the previous Tir Cynnal scheme was associated with a significantly higher percentage of respondents increasing the proportion of manures spread during the growing season, with a marginal effect of 11.3% (*generalised linear model,* P 0.03) (**Table 7.7**). This indicates that there is a legacy effect from the previous Tir Cynnal scheme.

Tables 7.8 to **7.13** summarise the count of manure management actions and uptake of specific actions by farm type and history of scheme participation. The results indicate that the contrast between DAIRY and CS farms is larger than the uplift caused by scheme participation.

Table 7.6. Average count of all manure management actions taken in the last three years, and the percent of farms taking specific action, stratified by farm type (*n* 494).

	DAIRY	CS-DA+CS-LOW	CS-SDA
Count of all actions (n)	3.3 (2.9 to 3.7)	1.7 (1.5 to 2.0)	1.6 (1.4 to 1.8)
Increased size of slurry store (%)	26.3 (18.6 to 33.9)	6.9 (4.2 to 10.6)	3.2 (1.1 to 5.9)
Bought or rented more land to spread manure (%)	31.4 (23.7 to 39.0)	5.8 (2.6 to 9.0)	5.9 (2.7 to 9.6)
Exported excess manure to another holding (%)	15.3 (9.3 to 22.0)	1.6 (0.0 to 3.7)	2.7 (0.5 to 4.8)
Roofed yard areas (%)	24.6 (16.9 to 32.2)	12.7 (7.9 to 18.0)	9.1 (5.3 to 13.4)
Separated 'dirty' yard water from runoff from clean concrete and roofs (%)	62.7 (53.4 to 71.2)	30.2 (23.8 to 37.6)	28.9 (22.5 to 35.3)
Reduced water usage for watering or cleaning livestock and buildings (%)	31.4 (23.7 to 40.7)	23.8 (17.5 to 30.2)	12.8 (8.0 to 17.6)
Covered manure heaps (%)	11.0 (5.9 to 16.9)	6.9 (3.7 to 10.6)	13.4 (9.1 to 18.7)
Moved manure heaps away from watercourse (%)	35.6 (27.1 to 44.9)	31.7 (25.4 to 38.1)	33.2 (26.2 to 39.6)
Calibrated manure spreader (%)	33.9 (26.3 to 42.4)	19.6 (13.8 to 24.9)	14.4 (9.6 to 19.8)
Increased proportion of manures spread during spring or growing season (%)	59.3 (50.8 to 67.8)	33.3 (26.5 to 40.2)	34.8 (27.8 to 41.2)

Table 7.7. Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken in the last three years, and the proportion of respondents taking specific actions (*n* 494).

Poisson Model Coefficients and Marginal Effects					
	Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Total Count of Actions	(Intercept)	1.09777	0.05704	19.246	<0.01
	Is_CS	-0.72151	0.06488	-11.121	<0.01
	Is_GEGA	0.25948	0.06321	4.105	<0.01
	AIC:	1884.2			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS	-1.72395	0.18221	-9.4612	<0.01
	Is_GEGA	0.51278	0.12683	4.0431	<0.01

Table 7.7 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken in the last three years, and the proportion of respondents taking specific actions (*n* 494).

Binomial Model Coefficients and Marginal Effects						
Increased the size of slurry store		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.4172	0.2601	-5.448	<0.01
		Is_CS	-2.0502	0.3262	-6.286	<0.01
		Is_GEGA	0.9490	0.3261	2.910	<0.01
		AIC:	283.61			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.222802	0.043168	-5.1612	<0.01
		Is_GEGA	0.067783	0.024554	2.7606	<0.01
Bought or rented more land to spread manure		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.7835	0.1984	-3.949	<0.01
		Is_CS	-1.9947	0.2961	-6.738	<0.01
		AIC:	318.36			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.255049	0.044391	-5.7455	<0.01
Exported excess manure to another holding		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.7148	0.2560	-6.697	<0.01
		Is_CS	-2.1138	0.4396	-4.808	<0.01
		AIC:	182.23			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.131266	0.033925	-3.8693	<0.01
Roofed yard areas		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.1213	0.2138	-5.244	<0.01
		Is_CS	-0.9792	0.2704	-3.622	<0.01
		AIC:	394.67			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.13672	0.04277	-3.1967	<0.01

Table 7.7 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken in the last three years, and the proportion of respondents taking specific actions (*n* 494).

Binomial Model Coefficients and Marginal Effects						
Reduced water usage for watering or cleaning livestock and buildings		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.8896	0.1398	-6.365	<0.01
		Is_CS-SDA	-0.9190	0.2548	-3.606	<0.01
		Is_TG	-0.5996	0.2995	-2.002	0.05
		AIC:	501.3			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS-SDA	-0.139103	0.034869	-3.9893	<0.01
		Is_TG	-0.087479	0.038770	-2.2563	0.02
Covered manure heaps		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.5649	0.2320	-11.054	<0.01
		Is_GEGA	0.7895	0.3026	2.609	<0.01
		AIC:	325.16			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_GEGA	0.073431	0.028561	2.571	0.01
Calibrated manure spreader		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.8506	0.2149	-3.959	<0.01
		Is_CS	-0.9773	0.2417	-4.043	<0.01
		Is_GEGA	0.4898	0.2276	2.152	0.03
		AIC:	495.56			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.179806	0.048513	-3.7064	<0.01
		Is_GEGA	0.080118	0.037604	2.1306	0.03
Increased proportion of manures spread during spring or growing season		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.2636	0.1944	1.356	>0.10
		Is_CS	-1.0676	0.2185	-4.886	<0.01
		Is_TC	0.4650	0.2075	2.241	0.03
		AIC:	642.71			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.259585	0.051642	-5.0266	<0.01
		Is_TC	0.112927	0.050726	2.2262	0.03

Table 7.7 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of manure management actions taken in the last three years, and the proportion of respondents taking specific actions (*n* 494).

Binomial Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Separated 'dirty' yard water from runoff from clean concrete and roofs		(Intercept)	0.5199	0.1904	2.731	<0.01
		Is_CS	-1.3901	0.2214	-6.278	<0.01
		AIC:	616.15			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.331906	0.050349	-6.5921	<0.01

Table 7.8. Average count of all manure management actions taken in the last three years, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		**DAIRY**	**CS-DA+CS-LOW**	**CS-SDA**
None	None	2.9 (2.4 to 3.5)	1.5 (1.1 to 2.0)	1.2 (0.8 to 1.7)
TC or TG	None	3.1 (2.6 to 3.7)	1.5 (1.1 to 1.9)	1.5 (1.1 to 1.9)
None	GE or GA	4.5 (3.6 to 5.5)	2.2 (1.6 to 2.8)	1.6 (1.1 to 2.0)
TC or TG	GE or GA	3.3 (2.3 to 4.4)	1.9 (1.4 to 2.5)	2.0 (1.4 to 2.6)

Table 7.9. Average percent of farms increasing the size of their slurry store, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		**DAIRY**	**CS-DA+CS-LOW**	**CS-SDA**
None	None	19.5 (7.3 to 31.7)	5.1 (0.0 to 10.2)	0.0 (0.0 to 0.0)
TC or TG	None	22.9 (8.6 to 37.1)	1.9 (0.0 to 5.6)	2.2 (0.0 to 6.7)
None	GE or GA	42.1 (21.1 to 63.2)	12.1 (3.0 to 24.2)	4.3 (0.0 to 10.6)
TC or TG	GE or GA	30.4 (13.0 to 52.2)	11.6 (2.3 to 23.3)	6.1 (0.0 to 14.3)

Table 7.10. Average percent of farms buying or renting more land to spread manure, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		**DAIRY**	**CS-DA+CS-LOW**	**CS-SDA**
None	None	22.0 (9.8 to 36.6)	3.4 (0.0 to 8.5)	0.0 (0.0 to 0.0)
TC or TG	None	37.1 (20.0 to 54.3)	7.4 (1.9 to 14.8)	4.4 (0.0 to 11.1)
None	GE or GA	36.8 (15.8 to 57.9)	3.0 (0.0 to 9.1)	8.5 (2.1 to 17.0)
TC or TG	GE or GA	34.8 (17.4 to 56.5)	9.3 (2.3 to 18.6)	10.2 (2.0 to 18.4)

Table 7.11. Average percent of farms exporting excess manure to another holding, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	7.3 (0.0 to 14.6)	0.0 (0.0 to 0.0)	2.2 (0.0 to 6.5)
TC or TG	None	22.9 (8.6 to 37.1)	1.9 (0.0 to 5.6)	0.0 (0.0 to 0.0)
None	GE or GA	5.3 (0.0 to 15.8)	3.0 (0.0 to 9.1)	2.1 (0.0 to 6.4)
TC or TG	GE or GA	26.1 (8.7 to 43.5)	2.3 (0.0 to 7.0)	6.1 (0.0 to 12.2)

Table 7.12. Average percent of farms roofing yard areas, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	12.2 (2.4 to 24.4)	8.5 (1.7 to 16.9)	6.5 (0.0 to 15.2)
TC or TG	None	31.4 (17.1 to 45.7)	13.0 (5.6 to 22.2)	11.1 (2.2 to 20.0)
None	GE or GA	47.4 (26.3 to 68.4)	15.2 (3.0 to 30.3)	8.5 (2.1 to 17.0)
TC or TG	GE or GA	17.4 (4.3 to 34.8)	16.3 (7.0 to 27.9)	10.2 (2.0 to 18.4)

Table 7.13. Average percent of farms separating ‘dirty’ yard water from runoff from clean concrete and roofs, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	63.4 (48.8 to 78.0)	30.5 (18.6 to 42.4)	30.4 (17.4 to 43.5)
TC or TG	None	57.1 (40.0 to 74.3)	25.9 (14.8 to 38.9)	28.9 (15.6 to 42.2)
None	GE or GA	78.9 (63.2 to 94.7)	36.4 (21.2 to 51.6)	31.9 (19.1 to 46.8)
TC or TG	GE or GA	56.5 (39.1 to 73.9)	30.2 (16.3 to 44.2)	24.5 (12.2 to 36.7)

Table 7.14. Average percent of farms reducing water usage for watering or cleaning livestock and buildings, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	36.6 (22.0 to 53.7)	23.7 (13.6 to 33.9)	15.2 (6.5 to 26.1)
TC or TG	None	20.0 (8.6 to 34.3)	20.4 (11.1 to 31.5)	8.9 (2.2 to 17.8)
None	GE or GA	57.9 (36.8 to 78.9)	27.3 (12.1 to 42.4)	17.0 (8.5 to 29.8)
TC or TG	GE or GA	17.4 (4.3 to 34.8)	25.6 (11.6 to 39.5)	10.2 (2.0 to 18.4)

Table 7.15. Average percent of farms covering manure heaps, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	7.3 (0.0 to 17.1)	3.4 (0.0 to 8.5)	8.7 (2.2 to 17.4)
TC or TG	None	5.7 (0.0 to 14.3)	9.3 (1.9 to 18.5)	8.9 (2.2 to 17.8)
None	GE or GA	31.6 (10.5 to 52.6)	6.1 (0.0 to 15.2)	17.0 (6.4 to 27.7)
TC or TG	GE or GA	8.7 (0.0 to 21.7)	9.3 (2.3 to 18.6)	18.4 (8.2 to 30.6)

Table 7.16. Average percent of farms moving manure heaps away from watercourses, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	48.8 (34.1 to 61.0)	27.1 (16.9 to 37.3)	26.1 (13.0 to 39.1)
TC or TG	None	28.6 (14.3 to 42.9)	25.9 (14.8 to 38.9)	31.1 (17.8 to 44.5)
None	GE or GA	21.1 (5.3 to 42.1)	42.4 (27.3 to 60.6)	34.0 (21.3 to 46.9)
TC or TG	GE or GA	34.8 (17.4 to 56.5)	37.2 (23.3 to 51.2)	40.8 (28.6 to 55.1)

Table 7.17. Average percent of farms calibrating manure spreaders, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	34.1 (19.5 to 48.8)	20.3 (10.2 to 30.5)	6.5 (0.0 to 15.2)
TC or TG	None	20.0 (8.6 to 34.3)	14.8 (5.6 to 25.9)	15.6 (6.7 to 26.7)
None	GE or GA	57.9 (36.7 to 78.9)	30.3 (15.2 to 45.5)	8.5 (2.1 to 17.0)
TC or TG	GE or GA	34.8 (17.4 to 52.2)	16.3 (7.0 to 27.9)	26.5 (14.3 to 38.8)

Table 7.18. Average percent of farms increasing the proportion of manures spread during the spring or growing season, stratified by farm type and history of scheme participation (*n* 494).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	39.0 (24.4 to 53.7)	32.2 (20.3 to 44.1)	28.3 (15.2 to 41.3)
TC or TG	None	68.6 (54.3 to 82.9)	29.6 (18.5 to 40.7)	37.8 (24.4 to 53.3)
None	GE or GA	73.7 (52.6 to 94.7)	42.4 (27.3 to 57.7)	27.7 (14.9 to 40.4)
TC or TG	GE or GA	69.6 (52.1 to 87.0)	32.6 (18.6 to 48.8)	44.9 (30.6 to 59.2)

There is evidence that participants in the Glastir scheme are more likely to have completed a Manure Management Plan. Farmers participating in the Glastir scheme carried out a greater number of manure management activities and were more likely to carry out specific management actions including increasing the size of slurry stores, covering manure heaps and calibrating manure spreaders.

The magnitude of participants completing a Manure Management Plan is similar to previous scheme participation. Whilst there was a legacy effect of previous Tir Cynnal scheme participation for the higher proportion completing a Manure Management Plan (likely to be a legacy of other legislative requirements), it appears that this does not translate through to the specific management actions, with the exception of increasing proportion of manures spread during the spring or growing season. This management action can be related to scheme requirements.

The increased uptake of specific management actions that have directly been associated with scheme participation may actually be a consequence of the completion of a Manure Management Plan. Participation in a scheme may result in an enhanced completion rate of Manure Management Plans. Establishing whether there is a direct effect of scheme on the update of management actions, or an indirect effect of a higher completion rate of Manure Management Plans will be analysed further and reported upon in the third report.

8. Soil Management

> Hypothesis: *scheme participation supports the completion of individual soil assessment or management reviews and uptake of specific soil management mitigation actions relevant to both arable and grassland for the control of diffuse air and water pollution.*

The purpose of a soil assessment or protection plan is to tackle degradation threats to soil. 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**). Therefore, carrying out appropriate measures to manage and protect soils will help prevent these problems.

Under the previous Tir Cynnal scheme, participants were required to produce a Farm Resource Management Plan and to update it annually in order to maintain acceptable water quality and minimise soil erosion. Although there was no specific obligation for participants to produce a Soil Protection Review or assessment, the Farm Resource Management Plan required under this scheme covered aspects of soil management that were included in the Single Payment Scheme (superseded by Basic Payment Scheme in 2015). Therefore participants in the Tir Cynnal scheme and also claiming Single Payment were perceived to have already had a Soil Protection Review in place and were therefore exempt from the need to complete a separate record, provided the Resource Management Plan obligations were adhered to (**Welsh Assembly Government, 2005c**).

Similarly, there was also no specific requirement for participants in the previous Tir Gofal scheme to produce a Soil Protection Review or assessment. Although it was essential that farmers in this scheme meet the requirements of Cross Compliance through Statutory Management Requirements (SMRs) and standards for keeping land in ‘Good Agricultural and Environmental Condition’ (GAEC). Prior to 2015 a specific GAEC required the completion of a Soil Protection Review to identify whether any soil erosion or management issues occur. However, this has since been replaced with a new set of minimum standards focusing on the condition of the land (**Farming Advice Service, 2015**), including ‘maintaining a minimum soil cover’ (GAEC 4), ‘minimising erosion’ (GAEC 5) and ‘maintaining good levels of soil organic matter’ (GAEC 6).

Like the previous agri-environment schemes, there is no specific obligation under the recently established Glastir scheme for participants to produce a Soil Protection Review or assessment. However, similar to the previous Tir Gofal, farmers must comply with Cross Compliance by keeping land in GAEC relating to the protection of soil, habitats and landscape features (**Welsh Assembly Government, 2013**). Under the ‘Whole Farm Code’ as part the Glastir scheme there are specific requirements relating to reducing soil erosion that require participants, where maize is grown, to chisel plough post-harvest to reduce compaction, under sow crop or break up soil compaction made by machinery and establish a winter cover crop. In addition there are a number of voluntary management options specifically related to reducing soil erosion and water runoff and minimising the risk of diffuse pollution. Under the targeted element of Glastir (Glastir Advanced), water quality, carbon stocks and soil erosion are the highest priorities. As a result, participants are encouraged to undertake voluntary management options that specifically relate to these priorities (**Welsh Assembly Government, 2016**). Therefore scheme participation was hypothesised to result in a greater awareness of soil management issues and the environmental significance of soil erosion, resulting in a higher implementation of mitigation actions relevant to both arable and grassland management.

This survey established the percentage of farms having completed a soil assessment or protection plan as a general indication of good practice. Information on specific soil management actions on both grassland and arable fields carried out by farmers was then collected to establish the rate of which good soil management practice was being put into practice.

Table 8.1 summarises the percent of farms completing a soil assessment or management review stratified by farm type and history of scheme participation. An overall average of 58.1% of farms had completed a soil assessment. There was a significant ($P<0.05$) effect of farm type with implementation higher on the DAIRY relative to the CS farms. There was a small but significant (P 0.05) effect of history of scheme participation, with implementation lower on farms that are not and have never been in scheme. The majority (74.2%) of soil assessments or management reviews were completed by the farmer or land manager. The percent of farmers completing management plans themselves did not vary significantly with scheme level (*Kruskal Wallis test*, $P>0.10$). The percent of farmers or land managers completing soil assessments themselves were significantly lower on DAIRY farms (65%) in comparison to the CS farms (P 0.05).

Table 8.1. Percent of farms completing a soil assessment or protection plan stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	70.7 (56.1 to 85.4)	50.8 (37.7 to 63.9)	37.5 (22.9 to 50.0)
TC or TG	None	54.3 (37.1 to 71.4)	54.5 (41.8 to 69.1)	58.3 (45.8 to 72.9)
None	GE or GA	68.4 (47.4 to 89.5)	59.5 (43.2 to 75.7)	53.2 (38.3 to 66.0)
TC or TG	GE or GA	82.6 (69.6 to 95.7)	61.4 (47.7 to 75.0)	68.0 (56.0 to 80.0)

The effect of farm type and history of scheme participation was highlighted during statistical modelling which establish that the percentage of respondents completing a soil assessment or management review were significantly lower on CS farms in comparison to the DAIRY farm type, with a calculated marginal effect of 14.7% (*generalised linear model,* $P<0.01$) (**Table 8.2**). Participation in the Glastir scheme and the previous Tir Cynnal scheme were associated with a significantly higher percent of farmers completing a soil assessment or management review in comparison with the background rate on non-scheme farms. The calculated marginal effect was 10.3 and 20.7% respectively (*generalised linear model,* P 0.02 and $P<0.01$) (**Table 8.2**).

Table 8.2. Coefficients and marginal effects of binomial model fitted to the proportion of respondents completing a soil assessment or protection plan (*n* 508).

Binomial Model Coefficients and Marginal Effects						
		Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
Completed a soil assessment or protection plan		(Intercept)	0.4009	0.2132	1.880	0.06
		Is_CS	-0.6348	0.2278	-2.787	<0.01
		Is_TC	0.9009	0.2177	4.138	<0.01
		Is_GEGA	0.4283	0.1889	2.268	0.02
		AIC:	668.56			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.147354	0.049852	-2.9558	<0.01
		Is_TC	0.206300	0.045796	4.5047	<0.01
		Is_GEGA	0.102915	0.044805	2.2970	0.02

Figure 8.1 and **Table 8.3** summarise the percentage of respondents testing fields for soil nutrient status over different time scales, stratified by farm type. The percentage of farmers testing fields for soil nutrient status on an annual basis, and very two years was 11.6 and 11% respectively. However, the majority of farmers (62.6%) tested field for soil nutrient status every three years or more, whereas 14.8% of farms did not test fields at all.

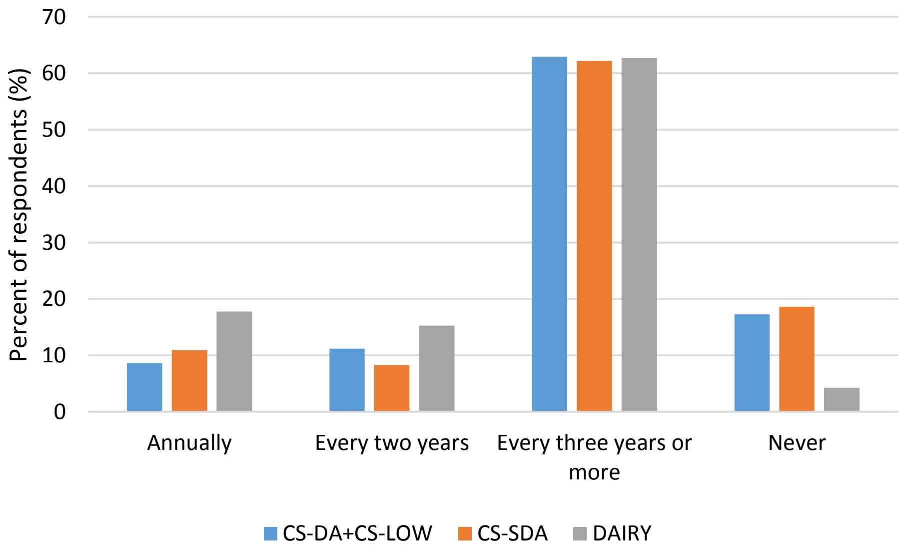

Figure 8.1. Percent of respondents testing fields for soil nutrient status over different time scales, stratified by farm type (*n* 508).

Table 8.3. Percent of respondents testing fields for nutrient status over different time scales (*n* 508).

Frequency of testing fields for soil nutrient status	Percent of respondents
Annually	11.6 (8.9 to 14.4)
Every two years	11.0 (8.5 to 13.6)
Every three years or more	62.6 (58.5 to 66.9)
Never	14.8 (11.8 to 17.9)

The percentage of respondents testing their fields for soil nutrient status on an annual basis were significantly lower on CS farms in comparison to the DAIRY farm type with a calculated marginal effect of 8.1% (*generalised linear model,* P 0.04). The percentage of respondents never testing their fields for soil nutrient status were significantly higher on CS farms in comparison to the DAIRY farm type. The calculated marginal effect was 13% (*generalised linear model,* P<0.01) (**Table 8.4**). Participation in the previous Tir Cynnal scheme was associated with a lower percent of farmers never testing their fields for soil nutrient status in comparison to the background rate of non-scheme farms, with a marginal effect of 7.5% (*generalised linear model,* P<0.01) (**Table 8.4**).

Table 8.4. Coefficients and marginal effects of binomial model fitted to the proportion of respondents testing fields for soil nutrient status over different timescales (*n* 508).

Binomial Model Coefficients and Marginal Effects						
Annually testing fields for soil nutrient status		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Intercept)	-1.5302	0.2407	-6.358	<0.01
		Is_CS	-0.6959	0.2951	-2.358	0.02
		AIC:	363.66			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.080530	0.038278	-2.1038	0.04
Never testing fields for soil Nutrient status		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.9684	0.4600	-6.453	<0.01
		Is_CS	1.6332	0.4768	3.425	<0.01
		Is_TC	-0.7673	0.3257	-2.356	0.02
		AIC:	408.24			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	0.135157	0.026053	5.1878	<0.01
		Is_TC	-0.075430	0.027971	-2.6967	<0.01

Figure 8.2 and **Table 8.5** summarise the percentage of respondents testing fields for pH and liming over different time scales, stratified by farm type. The percentage of farmers testing fields for pH and liming on an annual basis, and every two years was 14 and 9% respectively. However, the majority of farmers (65%) tested field for pH and liming every three years or more, whereas 12% of farms did not test fields at all.

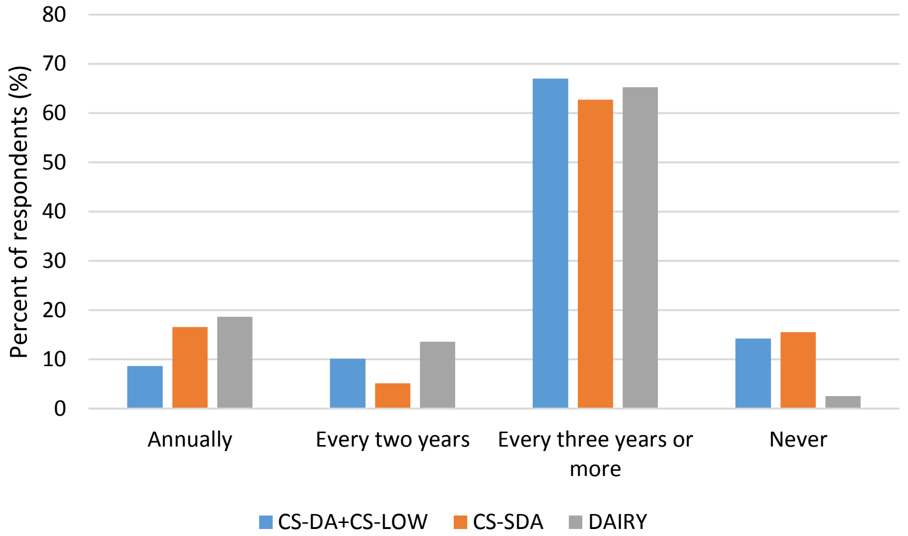

Figure 8.2. Percent of respondents testing fields for pH and liming over different time scales, stratified by farm type (*n* 508).

Table 8.5. Percent of respondents testing fields for pH and liming over different time scales (*n* 508).

Frequency of testing fields for pH and liming	Percent of respondents
Annually	14.0 (11.0 to 16.9)
Every two years	9.0 (6.7 to 11.4)
Every three years or more	65.0 (60.6 to 69.1)
Never	12.0 (9.1 to 15.2)

Statistical modelling established that there was a significant effect of farm type on the percentage of respondents annually and never testing fields for pH and liming. The percentage of respondents testing their fields for pH and liming on an annual basis were significantly lower for the CS-SDA farm type in comparison to the DAIRY farm type with a calculated marginal effect of 10.9% (*generalised linear model,* P 0.03). The percentage of respondents never testing their fields for pH and liming were significantly higher on CS farms in comparison to the DAIRY farm type. The calculated marginal effect was 12.3% (*generalised linear model,* P<0.01) (**Table 8.6**). The percent of farms testing fields for pH and liming over different time scales did not vary significantly with scheme type.

Table 8.6. Coefficients and marginal effects of binomial model fitted to the proportion of respondents testing fields for pH and liming over different timescales (*n* 508).

Binomial Model Coefficients and Marginal Effects					
	Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Intercept)	0.5978	0.1251	4.778	<0.01
	Is_CS-SDA	-0.4519	0.2056	-2.197	0.03
Annually testing fields for pH and liming	AIC:	575.45			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS-SDA	-0.108737	0.049673	-2.1891	0.03
	Model Coefficient	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-3.6463	0.5848	-6.235	<0.01
	Is_CS	1.9016	0.6019	3.159	<0.01
Never testing fields for pH and liming	AIC:	359.93			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS	0.123294	0.023121	5.3325	<0.01

Table 8.7 summarises the average total number of soil management actions taken on arable fields in the last three years and the percent of respondents taking action. There was a significant ($P<0.01$) effect of farm type with the average number of actions decreasing for the CS-SDA farm type relative to DAIRY farm type. Only 13% of respondents did not undertake any soil management actions on arable fields in the last three years. The actions most frequently implemented by the DAIRY farm type was delaying field operations to avoid working on wet soil (85.5%), followed by delaying cultivation for spring sown crops until the spring (76.4%). These actions were also most frequently implemented by the CS farms (68.4 and 53.2% respectively).

Statistical modelling established that the total number of soil management actions on arable fields were significantly lower on CS-SDA farms in comparison to the DAIRY farm type (*generalised linear model,* $P<0.01$). In general, CS-SDA farms carried out 1.89 fewer total actions (**Table 8.8**). The prevalence of the soil management actions involving minimal cultivation techniques, rough ploughing to remove harvest compaction, loosening or disrupting compacted tramlines, delaying tramline establishment, cultivating across slope and converting field corners to grass or bird cover did not differ between farm types or with history or scheme participation.

The percent of respondents carrying out soil management actions involving delaying field operations to avoid working on wet soil, delaying cultivation for spring sown crops until the spring and leaving autumn seed beds rough were significantly lower on CS farms in comparison to the DAIRY farm type. The calculated marginal effect was in the range of 15.8 and 22.2% (**Table 8.8**).

The percent of respondents establishing winter cover by early drilling, leaving stubble in field and establishing winter cover by sowing cover crop were significantly lower for the CS-SDA farm type in comparison to the DAIRY farm type. The calculated marginal effect was in the range of 18.1 and 30.7% (**Table 8.8**).

Participation in the Glastir Advanced scheme was associated with a significantly higher total number of soil management actions on arable fields (*generalised linear model,* P<0.01). Respondents in the Glastir Advanced scheme carried out 1.65 more total actions (**Table 8.8**). The percent of respondents leaving stubble in field as a soil management action on arable fields was significantly higher for farmers participating in the Glastir Advanced scheme, with a marginal effect of 25.4% (*generalised linear model,* P<0.01). Participation in the Glastir scheme in general was associated with a significantly higher percentage of respondents establishing vegetated and uncultivated buffer strips in comparison with the background rate of non-scheme farms. The calculated marginal effect was 25.7% (*generalised linear model,* P<0.01) (**Table 8.8**).

The absence of any differences between the DAIRY farm type and CS farms for this particular management option indicates that it was an effect of management intensity. This effect may be associated with certain agri-environment management options under the Glastir scheme including “Buffer zones to prevent erosion and run-off from land under arable cropping” and “Rough grass buffer zone to prevent erosion and run-off from land under arable cropping” (No, 158 and 174).

Tables 8.9 to **8.22** summarise the count of soil management actions and uptake of specific actions on arable fields by farm type and history of scheme participation.

Table 8.7. Average count of all specific soil management actions taken on arable fields in the last three years, and the percent of farms taking action, stratified by farm type (*n* 162).

	DAIRY	**CS-DA+CS-LOW**	**CS-SDA**
Count of all actions (n)	5.7 (4.8 to 6.4)	5.0 (4.1 to 5.9)	3.7 (2.8 to 4.6)
Established winter cover by early drilling (%)	30.9 (20.0 to 43.6)	35.0 (23.3 to 46.7)	14.9 (6.4 to 25.5)
Leave stubble in field (%)	61.8 (49.1 to 74.5)	45.0 (31.7 to 56.7)	27.7 (17.0 to 40.5)
Established winter cover by sowing cover crop (%)	36.4 (25.4 to 49.1)	45.0 (31.7 to 56.7)	19.1 (8.5 to 31.9)
Delayed field operations to avoid working on wet soil (%)	85.5 (76.4 to 94.5)	75.0 (63.3 to 85.0)	61.7 (48.9 to 74.5)
Used minimal cultivation techniques (%)	43.6 (30.9 to 56.4)	40.0 (28.3 to 53.3)	51.1 (36.2 to 63.8)
Rough ploughing to remove harvest compaction (%)	40.0 (27.3 to 52.7)	40.0 (28.3 to 53.3)	31.9 (19.1 to 44.7)
Loosened or disrupted compacted tramlines (%)	36.4 (25.5 to 49.1)	30.0 (18.3 to 41.7)	14.9 (6.4 to 25.5)
Delayed tramline establishment (%)	18.2 (9.1 to 29.1)	13.3 (5.0 to 21.7)	10.6 (2.1 to 19.1)
Delayed cultivation for spring sown crops until the spring (%)	76.4 (65.5 to 87.3)	61.7 (48.3 to 73.3)	44.7 (31.9 to 59.6)
Left autumn seed beds rough (%)	36.4 (23.6 to 49.1)	25.0 (15.0 to 35.0)	14.9 (6.4 to 25.5)
Cultivating across slope (%)	27.3 (16.4 to 40.0)	33.3 (23.3 to 45.0)	21.3 (10.6 to 34.0)
Established vegetated and uncultivated buffer strip (%)	36.4 (23.6 to 49.1)	26.7 (16.7 to 38.3)	25.5 (12.8 to 38.3)
Convert field corners to grass or bird cover (%)	36.4 (23.6 to 49.1)	30.0 (18.3 to 43.3)	27.7 (14.9 to 40.4)

Table 8.8. Coefficients and marginal effects of poisson and binomial models fitted to the total count of specific actions taken on arable fields in the last three years, and the proportion of respondents taking specific actions (*n* 162).

Poisson Model Coefficients and Marginal Effects					
Total Count of Actions	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	1.59704	0.04527	35.277	<0.01
	Is_CS-SDA	-0.43533	0.08783	-4.957	<0.01
	Is_GA	0.32158	0.07925	4.058	<0.01
	AIC:	886.83			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS-SDA	-1.89081	0.34632	-5.4597	<0.01
	Is_GA	1.65092	0.43853	3.7647	<0.01
Binomial Model Coefficients and Marginal Effects					
Established winter cover by early drilling	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-0.7062	0.1982	-3.562	<0.01
	Is_CS-SDA	-1.0368	0.4551	-2.278	0.02
	AIC:	189.49			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS-SDA	-0.181499	0.067976	-2.67	<0.01
Leave stubble in field	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-0.07253	0.20216	-0.359	>0.10
	Is_CS-SDA	-1.34260	0.40701	-3.299	<0.01
	Is_GA	1.04027	0.40656	2.559	0.01
	AIC:	213.47			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS-SDA	-0.307392	0.081546	-3.7696	<0.01
	Is_GA	0.254157	0.094332	2.6943	<0.01
Established winter cover by sowing cover crop	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-0.3694	0.1897	-1.947	0.05
	Is_CS-SDA	-1.0710	0.4164	-2.572	0.01
	AIC:	205.47			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS-SDA	-0.217206	0.073454	-2.957	<0.01

Table 8.8 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of specific actions taken on arable fields in the last three years, and the proportion of respondents taking specific actions (*n* 162).

Binomial Model Coefficients and Marginal Effects						
Delayed field operations to avoid working on wet soil		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.7707	0.3825	4.630	<0.01
		Is_CS	-0.9631	0.4360	-2.209	0.03
		AIC:	181.84			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.162957	0.065218	-2.4987	0.01
Delayed cultivation for Spring sown crops until the spring		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.1727	0.3174	3.695	<0.01
		Is_CS	-1.0041	0.3720	-2.699	<0.01
		AIC:	211.73			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.221580	0.074844	-2.9606	<0.01
Left autumn seed beds rough		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.5596	0.2803	-1.996	0.05
		Is_CS	-0.7920	0.3685	-2.149	0.03
		AIC:	184.83			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.158029	0.075722	-2.087	0.04
Established vegetated and and uncultivated buffer strip		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.6247	0.3034	-5.354	<0.01
		Is_GEGA	1.3089	0.3761	3.480	<0.01
		AIC:	187.67			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_GEGA	0.257130	0.068399	3.7593	<0.01

Table 8.9. Average count of all soil management actions taken on arable fields in the last three years, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		**DAIRY**	**CS-DA+CS-LOW**	**CS-SDA**
None	None	5.4 (3.7 to 7.3)	4.4 (3.2 to 5.7)	1.7 (0.5 to 3.1)
TC or TG	None	4.8 (3.4 to 6.2)	5.4 (3.4 to 7.2)	3.7 (2.2 to 5.2)
None	GE or GA	6.1 (4.4 to 7.8)	4.5 (2.5 to 6.5)	4.7 (3.3 to 6.0)
TC or TG	GE or GA	6.6 (5.2 to 8.0)	6.2 (4.6 to 7.9)	3.9 (2.4 to 5.7)

Table 8.10. Average percent of farms establishing winter cover by early drilling, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	26.7 (6.7 to 46.7)	23.8 (4.8 to 42.9)	10.0 (0.0 to 30.0)
TC or TG	None	31.3 (12.5 to 56.3)	45.5 (18.2 to 72.7)	0.0 (0.0 to 0.0)
None	GE or GA	36.4 (9.1 to 63.6)	40.0 (13.3 to 66.7)	13.3 (0.0 to 33.3)
TC or TG	GE or GA	30.8 (7.7 to 53.8)	38.5 (15.2 to 69.2)	25.0 (6.3 to 43.8)

Table 8.11. Average percent of farms leaving stubble in fields, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	66.7 (46.7 to 86.7)	52.4 (28.6 to 71.4)	10.0 (0.0 to 30.0)
TC or TG	None	43.8 (18.8 to 68.8)	45.5 (18.2 to 72.7)	16.7 (0.0 to 50.0)
None	GE or GA	90.9 (72.7 to 100.0)	26.7 (6.7 to 46.7)	33.3 (13.3 to 60.0)
TC or TG	GE or GA	53.8 (30.8 to 76.9)	53.8 (30.6 to 77.1)	37.5 (12.5 to 62.5)

Table 8.12. Average percent of farms establishing winter cover by sowing cover crop, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	33.3 (6.7 to 60.0)	52.4 (33.3 to 71.4)	20.0 (0.0 to 50.0)
TC or TG	None	37.5 (12.5 to 62.5)	36.4 (9.1 to 63.6)	16.7 (0.0 to 50.0)
None	GE or GA	36.4 (9.1 to 63.6)	46.7 (20.0 to 73.3)	13.3 (0.0 to 33.3)
TC or TG	GE or GA	38.5 (15.4 to 61.5)	38.5 (15.4 to 61.5)	25.0 (6.3 to 50.0)

Table 8.13. Average percent of farms delaying field operations to avoid working on wet soil, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	86.7 (66.7 to 100.0)	76.2 (57.1 to 95.2)	20.0 (0.0 to 50.0)
TC or TG	None	81.3 (62.5 to 100.0)	72.7 (45.5 to 90.9)	66.7 (33.3 to 100.0)
None	GE or GA	81.8 (54.5 to 100.0)	60.0 (33.3 to 86.7)	80.0 (60.0 to 100.0)
TC or TG	GE or GA	92.3 (76.9 to 100.0)	92.3 (76.9 to 100.0)	68.8 (43.8 to 87.5)

Table 8.14. Average percent of farms using minimal cultivation techniques, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	13.3 (0.0 to 33.3)	33.3 (14.3 to 52.4)	50.0 (20.0 to 80.0)
TC or TG	None	43.8 (18.8 to 68.8)	45.5 (18.2 to 72.7)	83.3 (50.0 to 100.0)
None	GE or GA	45.5 (18.2 to 72.7)	40.0 (13.3 to 66.7)	60.0 (40.0 to 80.0)
TC or TG	GE or GA	76.9 (53.8 to 100.0)	46.2 (23.1 to 69.2)	31.3 (12.5 to 56.3)

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able 8.15. Average percent of farms rough ploughing to remove harvest compaction, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	40.0 (13.3 to 66.7)	38.1 (19.0 to 57.1)	30.0 (0.0 to 60.0)
TC or TG	None	31.3 (6.3 to 56.3)	27.3 (0.0 to 54.5)	16.7 (0.0 to 50.0)
None	GE or GA	45.5 (18.2 to 72.7)	46.7 (20.0 to 66.7)	40.0 (13.3 to 66.7)
TC or TG	GE or GA	46.2 (23.1 to 76.9)	46.2 (23.1 to 76.9)	31.3 (12.5 to 56.3)

Table 8.16. Average percent of farms loosening or disputing compacted tramlines, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	53.3 (26.7 to 80.0)	23.8 (4.8 to 42.9)	0.0 (0.0 to 0.0)
TC or TG	None	25.0 (6.3 to 50.0)	27.3 (0.0 to 54.5)	16.7 (0.0 to 50.0)
None	GE or GA	27.3 (0.0 to 54.5)	26.7 (6.7 to 53.3)	13.3 (0.0 to 33.3)
TC or TG	GE or GA	38.5 (15.4 to 61.5)	46.2 (23.1 to 69.4)	25.0 (6.3 to 43.8)

Table 8.17. Average percent of farms delaying tramline establishment, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	20.0 (0.0 to 40.0)	9.5 (0.0 to 23.8)	10.0 (0.0 to 30.0)
TC or TG	None	18.8 (0.0 to 37.5)	18.2 (0.0 to 45.5)	0.0 (0.0 to 0.0)
None	GE or GA	18.2 (0.0 to 45.5)	6.7 (0.0 to 20.0)	6.7 (0.0 to 20.0)
TC or TG	GE or GA	15.4 (0.0 to 38.5)	23.1 (0.0 to 46.2)	18.8 (0.0 to 37.5)

Table 8.18. Average percent of farms delaying cultivation for spring sown crops until the spring, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	73.3 (46.7 to 93.3)	57.1 (38.0 to 76.2)	20.0 (0.0 to 40.0)
TC or TG	None	62.5 (37.5 to 87.5)	72.7 (45.5 to 100.0)	66.7 (33.3 to 100.0)
None	GE or GA	90.9 (72.7 to 100.0)	53.3 (26.7 to 73.3)	66.7 (40.0 to 86.7)
TC or TG	GE or GA	84.6 (61.5 to 100.0)	69.2 (38.5 to 92.3)	31.3 (12.5 to 56.3)

Table 8.19. Average percent of farms leaving autumn seed beds rough, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	33.3 (13.3 to 60.0)	19.0 (4.8 to 33.3)	0.0 (0.0 to 0.0)
TC or TG	None	18.8 (0.0 to 43.8)	27.3 (0.0 to 54.5)	16.7 (0.0 to 50.0)
None	GE or GA	45.5 (18.2 to 73.0)	20.0 (0.0 to 40.0)	20.0 (0.0 to 40.0)
TC or TG	GE or GA	53.8 (30.6 to 76.9)	38.5 (7.7 to 61.5)	18.8 (0.0 to 37.5)

Table 8.20. Average percent of farms cultivating across slope, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	20.0 (0.0 to 40.0)	23.8 (9.5 to 42.9)	0.0 (0.0 to 0.0)
TC or TG	None	31.3 (12.5 to 56.3)	54.5 (27.3 to 81.8)	33.3 (0.0 to 66.7)
None	GE or GA	18.2 (0.0 to 45.5)	33.3 (13.3 to 60.0)	33.3 (13.3 to 60.0)
TC or TG	GE or GA	38.5 (15.2 to 69.2)	30.8 (7.7 to 53.8)	18.8 (0.0 to 37.5)

Table 8.21. Average percent of farms establishing vegetated and uncultivated buffer strips, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	33.3 (13.3 to 60.0)	9.5 (0.0 to 23.8)	0.0 (0.0 to 0.0)
TC or TG	None	25.0 (6.3 to 43.8)	18.2 (0.0 to 45.5)	0.0 (0.0 to 0.0)
None	GE or GA	45.5 (18.2 to 72.7)	33.3 (13.3 to 60.0)	46.7 (20.0 to 73.3)
TC or TG	GE or GA	46.2 (15.4 to 76.9)	53.8 (30.8 to 76.9)	31.3 (12.5 to 56.3)

Table 8.22. Average percent of farms converting field corners to grass or bird cover, stratified by farm type and history of scheme participation (*n* 162).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	40.0 (20.0 to 66.7)	23.8 (4.8 to 42.9)	0.0 (0.0 to 0.0)
TC or TG	None	31.3 (12.5 to 56.3)	45.5 (18.2 to 72.7)	33.3 (0.0 to 83.3)
None	GE or GA	27.3 (0.0 to 54.5)	13.3 (0.0 to 33.3)	40.0 (13.3 to 60.2)
TC or TG	GE or GA	46.2 (15.4 to 76.9)	46.2 (23.1 to 76.9)	31.3 (6.3 to 56.3)

Table 8.23 summarises the average total number of soil management actions taken on grassland fields in the last three years and the percent of respondents taking action. The overall average number of actions was similar with the number of actions being taken on arable fields. There was a significant (P<0.01) effect of farm type with the average number of actions higher on the DAIRY relative to the CS farms. Only 5.6% of respondents did not take any soil management actions on grassland fields in the last three years. The action most frequently implemented by the DAIRY farm type was providing in-field watering points (85%), whereas the most frequently implemented action by the CS farms was re-siting or regularly rotating feeding sites (66.3%).

Statistical modelling established that the total number of soil management actions on grassland fields were significantly lower on CS farms in comparison to the DAIRY farm type (*generalised linear model,* P<0.01). In general, CS farms carried out 1.08 fewer total actions (**Table 8.24**). The prevalence of the soil management actions involving reducing stocking rate on fields subject to poaching, improving drainage on poached fields and no longer out-wintering cattle did not differ between farm types or with history of scheme participation.

The percent of respondents carrying out soil management actions involving delaying putting stock out to grass (*generalised linear model,* P 0.03), reducing length of grazing season or day (*generalised linear model,* P 0.04), removing compaction by re-seeding or soil loosening and fencing off streams from livestock (*generalised linear model,* P<0.01) were significantly lower on CS farms in comparison to the DAIRY farm type. The calculated marginal effect was in the range of 11.1 and 30.2% (**Table 8.24**).

The percent of respondents providing in-field watering points were significantly lower for the CS-SDA and CS-DA+CS-LOW farm types in comparison to the DAIRY farm type, with a marginal effect of 41.3 and 28.5% respectively (*generalised linear model,* P 0.01) (**Table 8.24**).

Participation in the Glastir scheme in general was associated with a significantly higher total number of soil management actions on grassland fields (*generalised linear model,* P 0.01). Respondents in the Glastir scheme carried out 0.53 more total actions (**Table 8.24**). Participation in the Advanced level of Glastir was associated with a significantly higher percentage of respondents fencing off streams from livestock and re-siting or regularly rotating feeding sites. The former of these management actions directly relates to the Glastir agri-scheme management prescription “Streamside corridor management” (No. 173) that restricts livestock from entering stream corridors. The calculated marginal effect was 29.4 and 16.2% respectively (*generalised linear model,* P<0.01) (**Table 8.24**).

Table 8.23. Average count of all soil management actions taken on grassland fields in the last three years, and the percent of farms taking specific action, stratified by farm type (*n* 430).

	DAIRY	CS-DA+CS-LOW	CS-SDA
Count of all actions (n)	5.4 (5.0 to 5.8)	4.5 (4.2 to 4.8)	4.2 (3.8 to 4.6)
Delayed putting stock out to grass (%)	69.2 (60.7 to 77.6)	61.6 (54.7 to 68.6)	53.6 (45.0 to 61.6)
Reduced stocking rate on field subject to poaching (%)	67.3 (57.9 to 75.7)	61.6 (54.1 to 68.0)	64.2 (57.0 to 70.9)
Reduced length of grazing season or day (%)	50.5 (40.2 to 59.8)	43.0 (35.5 to 50.0)	35.1 (27.2 to 43.0)
Improved drainage on poached fields (%)	41.1 (31.8 to 50.5)	39.5 (32.6 to 47.1)	33.1 (25.8 to 40.4)
Remove compaction by re-seeding or soil loosening (%)	80.4 (72.9 to 87.9)	52.3 (45.3 to 59.3)	47.7 (39.1 to 55.6)
Fenced off streams form livestock (%)	61.7 (53.3 to 71.0)	44.2 (37.2 to 51.2)	40.4 (32.5 to 48.3)
Provided in-field watering points (%)	85.0 (77.6 to 91.6)	62.2 (55.2 to 69.2)	48.3 (41.1 to 55.6)
Re-sited or regularly rotated feeding sites (%)	55.1 (44.9 to 64.5)	61.6 (54.1 to 69.2)	70.9 (63.6 to 78.1)
No longer out-winter cattle (%)	29.9 (21.5 to 39.3)	24.4 (18.0 to 30.8)	29.1 (21.9 to 35.8)

Table 8.24. Coefficients and marginal effects of poisson and binomial models fitted to the total count of actions taken on grassland fields in the last three years, and the proportion of respondents taking specific actions (*n* 430).

Poisson Model Coefficients and Marginal Effects					
Total Count of Actions	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	1.64280	0.04535	36.226	<0.01
	Is_CS	-0.22234	0.04958	-4.484	<0.01
	Is_GEGA	0.11347	0.04508	2.517	0.01
	AIC:	1966.6			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS	-1.08447	0.25518	-4.2499	<0.01
	Is_GEGA	0.52565	0.20994	2.5038	0.01
Binomial Model Coefficients and Marginal Effects					
Delayed putting stock out to grass	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Intercept)	0.8076	0.2093	3.858	<0.01
	Is_CS	-0.4891	0.2377	-2.057	0.04
	AIC:	575.9			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS	-0.112641	0.052422	-2.1487	0.03
Reduced length of grazing season or day	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	0.01869	0.19336	0.097	>0.10
	Is_CS	-0.45262	0.22442	-2.017	0.04
	AIC:	585.24			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS	-0.111484	0.055452	-2.0105	0.04
Remove compaction by re-seeding or soil loosening	**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	1.4098	0.2434	5.792	<0.01
	Is_CS	-1.4036	0.2676	-5.244	<0.01
	AIC:	557.74			
	Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
	Is_CS	-0.30219	0.047415	-6.3733	<0.01

Table 8.24 *cont.* Coefficients and marginal effects of poisson and binomial models fitted to the total count of actions taken on grassland fields in the last three years, and the proportion of respondents taking specific actions (*n* 430).

Binomial Model Coefficients and Marginal Effects						
Fenced off streams from livestock		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.3135	0.2039	1.538	>0.10
		Is_CS	-0.9389	0.2367	-3.967	<0.01
		Is_GA	1.2282	0.2486	4.941	<0.01
		AIC:	562.61			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	-0.229628	0.055032	-4.1726	<0.01
		Is_GA	0.294421	0.054117	5.4404	<0.01
Provided in-field watering points		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.7383	0.2711	6.412	<0.01
		Is_CS-SDA	-1.8045	0.3162	-5.706	<0.01
		Is_CS-DA+CS-LOW	-1.2398	0.3134	-3.956	<0.01
		AIC:	533.53			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_CS-SDA	-0.412928	0.065402	-6.3137	<0.01
		Is_CS-DA+CS-LOW	-0.284877	0.068880	-4.1358	<0.01
Re-sited or regularly rotated feeding sites		**Model Coefficient**	**Estimate**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.3854	0.1120	3.441	<0.01
		Is_GA	0.7541	0.2599	2.902	<0.01
		AIC:	560.46			
		Marginal Effect	**dF/dx**	**Std.Error**	**Z Value**	**Pr(>|z|)**
		Is_GA	0.162410	0.050823	3.1956	<0.01

Tables 8.25 to **8.34** summarise the count of soil management actions and uptake of specific actions on grassland fields by farm type and history of scheme participation.

Table 8.25. Average count of all soil management actions taken on grassland fields in the last three years, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	5.6 (4.9 to 6.3)	4.5 (3.9 to 5.1)	3.2 (2.5 to 4.0)
TC or TG	None	4.6 (3.9 to 5.4)	4.2 (3.5 to 4.9)	4.3 (3.6 to 5.1)
None	GE or GA	5.6 (4.8 to 6.3)	4.8 (4.1 to 5.5)	4.5 (3.7 to 5.2)
TC or TG	GE or GA	6.0 (5.1 to 6.8)	4.5 (3.9 to 5.2)	4.7 (4.0 to 5.4)

Table 8.26. Average percent of farms delaying putting stock out to grass, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	80.6 (66.7 to 91.7)	61.8 (49.1 to 74.5)	47.1 (29.4 to 64.7)
TC or TG	None	51.6 (32.3 to 67.8)	55.8 (41.9 to 69.8)	50.0 (34.2 to 65.8)
None	GE or GA	61.1 (38.9 to 83.3)	69.7 (54.5 to 84.8)	56.8 (40.5 to 73.0)
TC or TG	GE or GA	81.8 (63.6 to 95.5)	61.0 (46.3 to 75.6)	59.5 (45.2 to 73.8)

Table 8.27. Average percent of farms reducing stocking rate on fields subject to poaching, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	69.4 (52.8 to 83.3)	63.6 (50.9 to 74.5)	58.8 (44.1 to 73.5)
TC or TG	None	64.5 (45.2 to 80.6)	51.2 (34.9 to 65.2)	65.8 (50.0 to 81.6)
None	GE or GA	61.1 (38.9 to 83.3)	75.8 (60.6 to 87.9)	64.9 (48.6 to 78.4)
TC or TG	GE or GA	72.7 (54.5 to 90.9)	58.5 (43.9 to 73.2)	66.7 (52.4 to 81.0)

Table 8.28. Average percent of farms reducing length of grazing season or day, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	55.6 (38.9 to 72.2)	52.7 (40.0 to 65.5)	32.4 (17.6 to 50.0)
TC or TG	None	35.5 (19.4 to 51.6)	39.5 (25.6 to 53.5)	26.3 (13.2 to 39.5)
None	GE or GA	55.6 (33.3 to 77.8)	30.3 (15.2 to 45.5)	32.4 (18.9 to 48.6)
TC or TG	GE or GA	59.1 (36.4 to 77.3)	43.9 (29.3 to 58.5)	47.6 (33.3 to 61.9)

Table 8.29. Average percent of farms improving draining on poached fields, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	52.8 (36.1 to 69.4)	40.0 (27.3 to 52.7)	14.7 (5.9 to 26.5)
TC or TG	None	22.6 (9.7 to 38.7)	44.2 (30.2 to 60.5)	39.5 (23.7 to 55.3)
None	GE or GA	33.3 (11.1 to 55.6)	39.4 (21.2 to 54.5)	40.5 (24.3 to 56.8)
TC or TG	GE or GA	54.5 (31.8 to 72.7)	34.1 (19.5 to 48.8)	35.7 (21.4 to 50.0)

Table 8.30. Average percent of farms removing compaction by re-seeding or soil loosening, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	80.6 (66.7 to 91.7)	52.7 (40.0 to 65.5)	32.4 (17.6 to 50.0)
TC or TG	None	74.2 (58.1 to 87.1)	60.5 (44.2 to 74.4)	60.5 (47.4 to 73.7)
None	GE or GA	94.4 (83.3 to 100.0)	54.5 (36.4 to 69.7)	48.6 (32.4 to 64.9)
TC or TG	GE or GA	77.3 (59.1 to 90.9)	41.5 (26.8 to 58.5)	47.6 (33.3 to 62.0)

Table 8.31. Average percent of farms fencing off streams from livestock, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	58.3 (41.7 to 75.0)	38.2 (27.3 to 50.9)	11.8 (2.9 to 23.5)
TC or TG	None	51.6 (32.3 to 67.7)	34.9 (20.9 to 51.2)	42.1 (26.3 to 57.9)
None	GE or GA	72.2 (50.0 to 88.9)	63.6 (48.5 to 81.8)	45.9 (29.7 to 62.2)
TC or TG	GE or GA	72.7 (54.5 to 90.9)	46.3 (31.7 to 61.0)	57.1 (42.9 to 71.5)

Table 8.32. Average percent of farms providing in-field watering points, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	75.0 (61.1 to 88.9)	56.4 (43.6 to 70.9)	41.2 (26.5 to 58.8)
TC or TG	None	87.1 (74.2 to 96.8)	69.8 (55.8 to 83.7)	52.6 (36.8 to 68.4)
None	GE or GA	88.9 (72.2 to 100.0)	63.6 (48.5 to 78.8)	51.4 (35.1 to 67.6)
TC or TG	GE or GA	95.5 (86.4 to 100.0)	61.0 (46.3 to 75.6)	47.6 (33.3 to 64.3)

Table 8.33. Average percent of farms re-siting or regularly rotating feeding sites, stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	55.6 (38.9 to 69.4)	60.0 (47.3 to 72.7)	58.8 (44.1 to 73.5)
TC or TG	None	45.2 (29.0 to 64.5)	53.5 (39.5 to 67.4)	73.7 (57.9 to 86.8)
None	GE or GA	77.8 (55.6 to 94.4)	66.7 (51.5 to 81.8)	70.3 (56.8 to 83.8)
TC or TG	GE or GA	50.0 (31.8 to 68.2)	68.3 (53.7 to 80.5)	78.6 (64.3 to 90.5)

Table 8.34. Average percent of farms no longer out-wintering cattle stratified by farm type and history of scheme participation (*n* 430).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	33.3 (19.4 to 50.0)	23.6 (12.7 to 34.5)	26.5 (11.8 to 41.2)
TC or TG	None	32.3 (16.1 to 48.4)	14.0 (4.7 to 25.6)	23.7 (10.5 to 36.8)
None	GE or GA	16.7 (0.0 to 33.3)	21.2 (9.1 to 36.4)	37.8 (21.6 to 54.1)
TC or TG	GE or GA	31.8 (13.6 to 54.5)	39.0 (24.4 to 53.7)	28.6 (14.3 to 42.9)

There is evidence that participants in the Glastir scheme are more likely to have completed a soil assessment or protection review. Farmers participating in the Glastir scheme carried out a greater number of soil management activities and were more likely to carry out specific management actions including leaving stubble in field and establishing vegetated and uncultivated buffer strips on arable fields, and fencing off streams from livestock and re-siting or regularly rotating feeding sites on grassland fields. The latter management action can be directly related to one of the requirements under the Glastir scheme.

The magnitude of participants completing a soil assessment or protection review is similar to previous scheme participation. Whilst there was a legacy effect of previous Tir Cynnal scheme participation for the higher proportion completing a soil protection plan (likely to be a legacy of other legislative requirements, for example Single Payment), it appears that this does not translate through to the specific management actions.

The increased uptake of specific management actions that have directly been associated with scheme participation may actually be a consequence of the completion of a Soil Protection Plan. Participation in a scheme may result in an enhanced completion rate of Soil Protection Plans. Establishing whether there is a direct effect of scheme on the update of management actions, or an indirect effect of a higher completion rate of Soil Protection Plans will be analysed further and reported upon in the third report.

9. Woodland Services

Hypothesis*: participation in agri-environment schemes supports the restoration and creation of farm woodland, and promotes the active management of woodland for services.*

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**). As farmland covers approximately 71% of land in Wales, much of this new woodland will need to be planted on current farmland (**Institute of Welsh Affairs, 2016**). Farms presently manage approximately one quarter, or 75,700ha, of the current woodland area (**Grove, 2015**). Supportive measures to encourage farm woodland restoration and planting have been in place since the 1950's (**Forestry Commission 2015**), through various schemes and grants, with Better Woodlands for Wales being the most popular until it ended in 2011 (**Grove, 2015**). The uptake of these schemes by farmers was increasing between 2000 and 2013 (**Grove, 2015**).

Only around 5% of woodlands in Wales have been designated for their international and national importance to nature conservation and of this only 26% is classed as in a favourable condition (**National Assembly for Wales, 2013**). However, woodlands can be used for a wide range of services with some bringing financial gains. At present only 3% of farm woodlands are used commercially, with the majority of farm woodlands not appearing to generate any kind of income (**Marsh, 2013**). Therefore, there is also a desire to increase the proportion of farmers harvesting firewood and timber from their woodland or generating income from woodlands in other ways in order to contribute to the resilience of the agricultural sector (**Groves, 2015**).

This survey recorded the numbers of respondents with woodland, the planting of new woodland, the receipt of grants for restoration or creation, and the active management of woodland for services.

The majority (73%) of survey respondent's farms had woodland, with an average area of 7 ha per farm (*n* 440). The percent of farms with woodland did not vary with farm type (*fisher exact test*, P>0.10) but those with a history of participation in the Glastir (P<0.01) scheme were marginally more likely to have woodland on farm (**Table 9.1**). Overall, 17% of farms had received some form of grant for woodland management (**Table 9.2**), and these farms had a significantly higher (14 ha) average area of woodland (*kruskal-wallis test*, P<0.01).

In contrast, an earlier survey by **Hughes (2012)** of 988 private woodland owners in Wales reported that roughly half were (or had been) participating in a grant scheme. It is believed that this difference may partly reflect that we did not ask specifically for information on grant payments related to the earlier Tir Gofal scheme, and more likely the effect of the minimum farm size used in the stratification of survey. **Anthony and Stopps (2016)** report that farms accounting for only 148 of 718 current Glastir woodland management agreements contributed to the survey sample pool. This was a 21% inclusion rate in comparison to rates of 64 and 61% for Glastir Entry and Advanced agreement holders. Our survey was clearly biased away from grant holders and in the final set of survey results there were only 46 respondents with a Glastir woodland management agreement (either woodland *management*, *restoration* or *creation*).

The percent of farms with woodland in receipt of a grant was significantly higher on farms having participated in the Tir Gofal scheme (**Table 9.3**), and currently participating in the Entry or Advanced levels of Glastir (*general linear model*, P<0.05). This analysis was

restricted to farms not participating in the Commons, Organic or Energy Efficiency elements of Glastir (*n* 372). The most common grants received were the current Glastir “Woodland Management” (7%) and the earlier “Woodland Grant Scheme” (7%) managed by The Forestry Commission (**Table 9.2**).

Table 9.1 a) Percent of respondents farms having woodland, and b) the average woodland area (ha) on those farms, stratified by farm type and scheme participation history (*n* 440)

a) Having Woodland (%)

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	73 (60 to 84)	66 (55 to 79)	62 (48 to 76)
TC or TG	None	80 (68 to 91)	62 (51 to 75)	75 (62 to 87)
None	GE or GA	77 (59 to 91)	65 (50 to 80)	77 (65 to 87)
TC or TG	GE or GA	82 (68 to 96)	84 (74 to 86)	76 (66 to 86)

b) Woodland Area (ha)

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	2.5 (1.6 to 3.5)	3.0 (2.0 to 4.3)	4.7 (3.0 to 6.4)
TC or TG	None	4.1 (2.7 to 5.9)	7.2 (4.0 to 11.4)	11.7 (3.9 to 26.6)
None	GE or GA	2.2 (1.4 to 3.1)	8.3 (3.2 to 15.8)	9.6 (5.2 to 17.8)
TC or TG	GE or GA	8.5 (5.4 to 12.7)	4.6 (3.3 to 6.2)	13.6 (7.4 to 22.5)

Table 9.2 a) Percent of respondents in receipt of a grant for woodland management, and b) percent of all surveyed woodland on those farms, stratified by farm type and grant aid scheme (*n* 440).

a) Receipt of a Grant (%)

Farm Type	Number Farm type	Woodland Grant Scheme	Better Woodlands for Wales	Glastir management	Glastir Creation	Glastir Restoration	No Grant
CS-DA+CS-LOW	161	6 (2 to 9)	1 (0 to 2)	7 (4 to 11)	4 (1 to 8)	1 (0 to 3)	84 (78 to 89)
CS-SDA	169	9 (5 to 13)	2 (1 to 5)	8 (4 to 13)	5 (2 to 8)	1 (0 to 3)	78 (71 to 83)
DAIRY	110	6 (3 to 12)	2 (0 to 5)	5 (1 to 8)	2 (0 to 5)	3 (0 to 6)	88 (83 to 94)
ALL	440	7 (5 to 10)	2 (1 to 3)	7 (5 to 9)	4 (2 to 5)	2 (1 to 3)	83 (79 to 86)

b) Percent of Surveyed Woodland Area (%)

Farm Type	Woodland Area (ha)	Woodland Grant Scheme	Better Woodlands for Wales	Glastir management	Glastir Creation	Glastir Restoration	No Grant
CS-DA+CS-LOW	759	24 (8 to 40)	0 (0 to 0)	14 (1 to 32)	20 (2 to 37)	13 (0 to 31)	62 (46 to 80)
CS-SDA	1587	13 (5 to 24)	19 (1 to 40)	9 (3 to 19)	10 (2 to 23)	1 (0 to 4)	57 (39 to 75)
DAIRY	749	11 (2 to 29)	1 (0 to 4)	10 (1 to 27)	1 (0 to 5)	2 (0 to 7)	85 (65 to 96)
ALL	3096	15 (8 to 24)	10 (1 to 24)	11 (4 to 19)	10 (4 to 18)	4 (1 to 10)	65 (52 to 78)

Overall, 16% of respondents had restored or created woodland in the past three years (*n* 440), and this was significantly higher for participants in the Entry or Advanced level of the Glastir scheme, or in receipt of a woodland management grant (*general linear model*, P<0.01). The marginal effects were 11% and 20% respectively (**Table 9.4**). The percent of respondents in receipt of a grant who would not have proceeded with woodland restoration or creation without grant support was 75% (*n* 28). **Cao and Elliott (2015)** in their survey of 942 farms for uptake of the Glastir woodland management grants reported that 36% of all respondents had planted new woodland in the previous ten years, made up of 53% of respondents with a woodland management grant (*n* 413) and 12% of respondents without a grant (*n* 592). In this survey, we similarly found that 36% of respondents with a grant (*n* 77) had restored or created woodland in the past three years, and 12% without a grant (*n* 363).

Of those who had not taken up a grant for woodland management, the main reasons cited after a general "*not interested in woodland management*" included "*lack of available land*" (29%), "*insufficient time to diversify*" (28%), "*insufficient knowledge or equipment*" (28%) and the "*scheme was too complicated*" (27%). The reasons cited did not vary with woodland area (**Table 9.5**).

Respondents were less likely to declare that they were ""*not interested in woodland management*" if they had previously participated in the Tir Gofal scheme, or were participating in the Entry or Advanced levels of Glastir (*general linear model*, P<0.05) (**Table 9.6**). Respondents were more likely to declare that they were "*not interested in woodland management*" if they also declared that they "*had insufficient time to diversity*" (P<0.05) or that "*market prices for timber are low*" (P<0.01) (*general linear model*).

Overall, 87% of respondents actively managed their woodland for one or more services (**Tables 9.7 and 9.8**). This result is markedly higher than the 47% reported by **Cao and Elliott (2015)** in their survey for uptake of the Glastir woodland management grants. That survey asked respondents, including non-beneficiaries, whether woodland was actively managed for any reason prior to collecting details of the specific activities. In contrast, this survey immediately presented respondents with a list of activities to select from. It is suggested that respondents in the **Cao and Elliott (2015)** survey therefore had a more limited pre-conception of what woodland management might mean and were less likely to respond positively to the question.

There was no significant difference in the total number of services managed by farm type or scheme participation history (*general linear model*, P>0.10; **Table 9.9**). However, management for "*provision of fuel or firewood*" was significantly less likely on farms in receipt of a woodland management grant (P<0.05), whilst management for "*provision of timber*" increased with the woodland area (P<0.05; **Table 9.9**). The prevalence of management of woodland for "*shelter for livestock*" was significantly lower on farms participating in the Advanced level of Glastir, and management for "*wildlife habitat*" was significantly higher (P<0.05). The marginal effects were 16 and 21% respectively. Management for "*shelter for livestock*" was also significantly higher on the CS farm types (P<0.01).

Overall, respondents most frequently managed all or part of their woodland for "wildlife habitat" (62%), "livestock shelter" (52%) and "fuel or firewood" (44%) (**Table 9.7**). The survey rankings match those reported by **Cao and Elliott (2015)** who reported that farmers were most frequently motivated to manage woodland for the "*benefit of wildlife*" (92"), "*to provide shelter*" (68%) and "*to provide wood fuel for personal use*" (66%). However, **Cao and Elliott (2015)** make a potentially important distinction between provision of "fuel or firewood for personal use" (44%) and "to provide wood fuel for sale" (18%). Similarly, they make a distinction between "provision of a place for personal recreation and relaxation" (47%) and "to provide public access and recreation" (23%). It is clearly important to recognise the separate private and public services resulting from woodland management.

Participation in the Glastir scheme, and specifically receipt of a grant for woodland management, has resulted in woodland restoration and creation on an estimated 5 and 15% of farms in scheme that would otherwise not have occurred – above the minimum farm size. The farms in receipt of grant typically owned twice the area of woodland found on other farms. In comparison with the percent of respondents with woodland who stated that they were "not interested in woodland management" (44%) there is some opportunity for further planting providing resource issues of complexity and available time for diversification can be overcome.

The effect on service provision is mixed, depending on the source of support. Farms in receipt of a woodland management grant are less likely to use part or all of their woodland for provision of fuel or firewood. Farms participating in the Glastir scheme are less likely to manage their woodland for livestock shelter, and more likely to manage for wildlife habitat. It is believed that 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. Whilst active management of woodland for service provision includes a mix of private and public goods, such as provision of firewood and wildlife habitat (55 and 58% of farms with woodland), it typically does not include public access to woodland areas by way of education, sports and recreation (14 and 18% of farms with woodland).

Table 9.3 Coefficients and marginal effects of binomial model fitted to the proportion of respondents with woodland in receipt of a grant for woodland management (*n* 372).

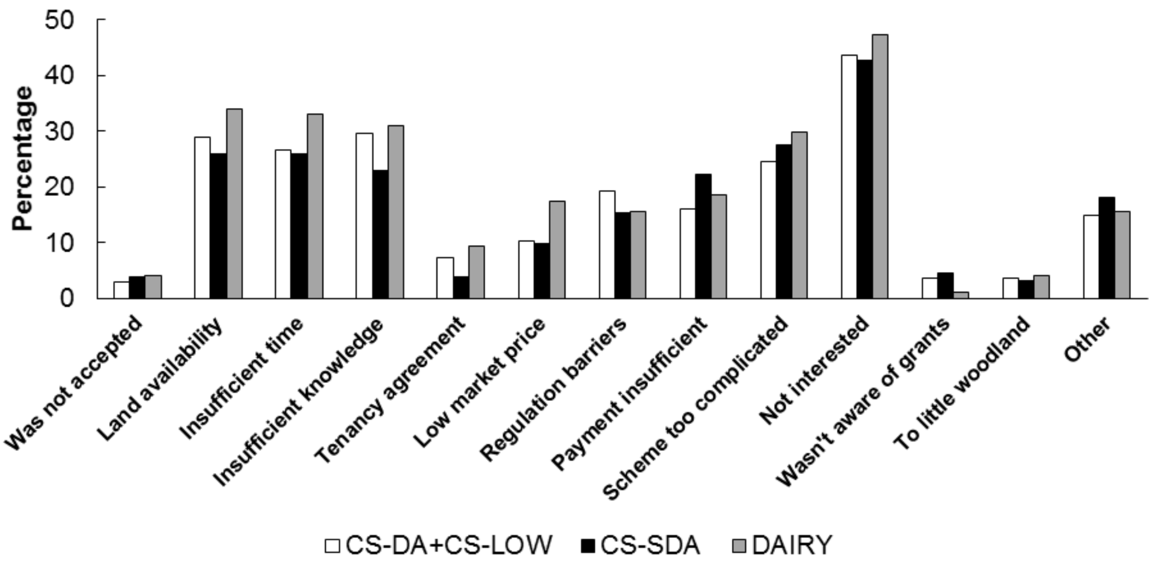
Binomial Model Coefficients and Marginal Effects						
Receipt of grant		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.8978	0.3069	-9.441	P<0.01
		Is_TG	0.6615	0.2753	2.403	P<0.05
		Is_GEGA	1.1709	0.3729	3,140	P<0.01
		Is_GA	0.9260	0.3079	3.008	P<0.01
		AIC	365			
		Marginal Effect	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		Is_TG	0.087	0.039	2.203	P<0.05
		Is_GEGA	0.137	0.040	3.400	P<0.01
		Is_GA	0.129	0..049	2.590	P<0.01

Table 9.4 Coefficients and marginal effects of a binomial model fitted to the proportion of respondents with woodland that have restored or planted new woodland in the past three years (*n* 364).

Binomial Model Coefficients and Marginal Effects					
	Model Coefficient	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-2.489	0.261	-9.522	0.000
	Is_GEGA	0.960	0.324	2.963	0.003
	Is_Grant	1.274	0.347	3.673	0.000
Restoration or planting of new woodland	AIC:	293.290			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	Is_GEGA	0.116	0.039	2.986	0.003
	Is_Grant	0.202	0.068	2.957	0.003

Figure 9.1 Reasons cited for prevention or delaying of application for grants for woodland planting or management, expressed as a) percentage of respondents and b) percentage of the surveyed woodland area, stratified by farm type (*n* 363).

a) Percent of Respondents (%)



b) Percent of Surveyed Woodland Area (%)

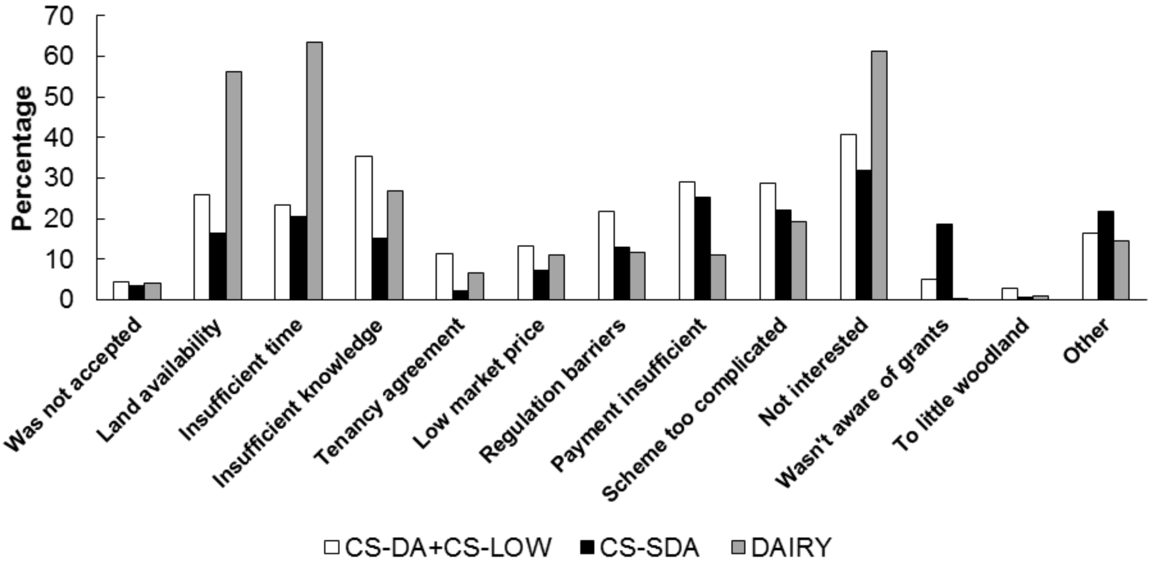


Table 9.5 Reasons cited for prevention or delaying of application for grants for woodland planting or management, expressed as a percentage of respondents and as a percentage of the surveyed woodland area (*n* 363).

Main Reasons	Respondents (%)	Woodland Area (%)
Applied but not accepted	4 (2 to 6)	4 (1 to 7)
Land availability for planting	29 (25 to 34)	31 (17 to 48)
Insufficient time to diversify	28 (23 to 33)	35 (20 to 50)
Insufficient knowledge or equipment	28 (23 to 32)	24 (16 to 33)
Tenancy agreement	7 (4 to 9)	6 (2 to 11)
Low market price for timber	12 (9 to 15)	10 (6 to 15)
Deterred by regulations	17 (13 to 21)	15 (9 to 22)
Payment insufficient	19 (15 to 23)	22 (14 to 31)
Scheme too complicated	27 (22 to 31)	23 (15 to 32)
Not interested	44 (39 to 50)	43 (29 to 59)
Unaware of grants	3 (2 to 5)	10 (1 to 25)
To little woodland	4 (2 to 6)	1 (0 to 2)
Other	16 (13 to 20)	18 (11 to 27)

Table 9.6 Coefficients and marginal effects of binomial model fitted to the proportion of respondents with woodland and not in receipt of a grant declaring that they were "not interested in woodland management" (*n* 312).

Binomial Model Coefficients and Marginal Effects					
	Model Coefficient	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	0.0761	0.1992	0.382	0.703
	Is_TG	-0.6200	0.2957	-2.096	P<0.05
	Is_GEGA	-0.5690	0.2452	-2.320	P<0.05
	Insufficient_Time	0.5472	0.2756	1.987	P<0.05
	Low_Prices	1.0767	0.4358	2.470	P<0.05
Not Interested in Woodland Management	Insufficient_Payment	-0.6852	0.3203	-2.139	P<0.05
	Marginal Effect	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	Is_TG	-0.1489	0.0678	-2.1963	P<0.05
	Is_GEGA	-0.1393	0.0589	-2.3648	P<0.05
	Insufficient_Time	0.1359	0.0678	2.0034	P<0.05
	Low_Prices	0.2597	0.0957	2.7117	P<0.01
	Insufficient_Payment	-0.1641	0.0729	-2.2509	P<0.05

Table 9.7 a) Percent of respondents with woodland actively managing part or all of the woodland area for specific services, b) percent of the surveyed woodland area on those farms, stratified by receipt of a woodland management grant.

a) Percent of Respondents (%)

Service	Grant (*n* 77)	No Grant (*n* 363)	All
Fuel or firewood	29 (19 to 42)	46 (41 to 52)	44 (39 to 49)
Timber	19 (10 to 31)	12 (8 to 15)	13 (10 to 16)
Sports and recreation	8 (2 to 15)	4 (2 to 6)	4 (2 to 6)
Livestock shelter	38 (25 to 52)	54 (49 to 60)	52 (47 to 57)
Public access and education	12 (4 to 21)	9 (5 to 12)	9 (6 to 12)
Wildlife habitat	75 (63 to 87)	59 (54 to 64)	62 (56 to 66)
Watercourse protection	44 (31 to 58)	39 (34 to 44)	40 (35 to 45)
Biosecurity	35 (21 to 48)	36 (31 to 42)	36 (31 to 41)
Carbon sequestration	23 (12 to 35)	13 (9 to 17)	14 (11 to 18)
None	12 (4 to 21)	15 (11 to 19)	14 (11 to 18)

Table 9.7 cont. *a) Percent of respondents with woodland actively managing part or all of the woodland area for specific services, b) percent of the surveyed woodland area on those farms, stratified by receipt of a woodland management grant.*

b) Percent of Surveyed Woodland Area (%)

Service	Grant (1089 ha)	No Grant (2005 ha)	All (3095 ha)
Woodland Area	1089.75	2005.85	3095.36
Fuel or firewood	55 (23 to 77)	52 (36 to 66)	53 (36 to 66)
Timber	48 (15 to 71)	15 (8 to 24)	26 (13 to 41)
Sports and recreation	18 (0 to 42)	5 (2 to 9)	9 (2 to 17)
Livestock shelter	61 (30 to 80)	39 (26 to 55)	46 (32 to 61)
Public access and education	14 (2 to 36)	8 (4 to 13)	10 (4 to 18)
Wildlife habitat	58 (33 to 88)	56 (38 to 73)	57 (40 to 73)
Watercourse protection	65 (33 to 83)	30 (20 to 43)	41 (28 to 56)
Biosecurity	23 (8 to 48)	27 (18 to 41)	26 (18 to 38)
Carbon sequestration	20 (6 to 44)	8 (5 to 13)	12 (7 to 20)
None	11 (1 to 29)	13 (7 to 22)	13 (7 to 20)

Table 9.8 Percent of the surveyed woodland area on farms actively managing part or all of the woodland area for specific services, stratified by farm type.

Service	CS-DA+CS-LOW (759 ha)	CS-SDA (1587 ha)	DAIRY (749 ha)	All (3095 ha)
Fuel or firewood	49 (31 to 66)	50 (28 to 70)	64 (29 to 83)	53 (36 to 66)
Timber	23 (5 to 42)	35 (14 to 56)	9 (2 to 26)	26 (13 to 41)
Sports and recreation	17 (1 to 39)	7 (0 to 18)	6 (2 to 16)	9 (2 to 17)
Livestock shelter	47 (29 to 63)	60 (40 to 78)	16 (7 to 36)	46 (32 to 61)
Public access and education	21 (4 to 41)	5 (1 to 11)	9 (3 to 24)	10 (4 to 18)
Wildlife habitat	70 (55 to 83)	61 (39 to 80)	35 (17 to 69)	57 (40 to 73)
Watercourse protection	52 (34 to 68)	44 (23 to 64)	25 (12 to 51)	41 (28 to 56)
Biosecurity	45 (28 to 61)	19 (10 to 31)	24 (10 to 50)	26 (18 to 38)
Carbon sequestration	26 (8 to 47)	6 (3 to 12)	13 (4 to 31)	12 (7 to 20)
None	19 (7 to 34)	10 (3 to 20)	12 (5 to 30)	13 (7 to 20)

Table 9.9 Coefficients and marginal effects of poisson and binomial models fitted to the total count of services and the proportion of respondents who are actively managing woodland for specific services (*n* 364).

Poisson and Binomial Model Coefficients and Marginal Effects						
Count of Services		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	1.00760	0.03167	31.820	>0.01
		AIC:	1497.9			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		n/a	n/a	n/a	n/a	n/a
Fuel and firewood		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.141	0.114	-1.244	>0.01
		Is_Grant	-0.762	0.327	-2.333	<0.05
		AIC:	497.45			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		Is_Grant	-0.176	0.069	-2.559	<0.05
Timber for other uses		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-2.154	0.196	-10.982	<0.01
		Is_Area>7ha	0.840	0.330	2.544	<0.05
		AIC:	279.65			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		Is_Area>7ha	0.108	0.048	2.249	<0.05
Shelter for livestock		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-0.045	0.143	-0.315	>0.01
		Is_CS	0.761	0.225	3.386	<0.01
		Is_GA	-0.662	0.259	-2.553	<0.05
		AIC:	492.68			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		Is_CS	0.186	0.053	3.497	<0.01
		Is_GA	-0.164	0.063	-2.621	<0.01
Wildlife habitat		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.265	0.120	2.201	<0.05
		Is_GA	1.019	0.292	3.487	<0.01
		AIC:	475.47			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		Is_GA	0.217	0.054	4.021	<0.01

10. Renewable Energy

Hypothesis*: installation of on-farm renewable energy makes an important contribution to off-setting the carbon footprint of agricultural production.*

The *Renewable Energy Directive* (2009/28/EC) establishes a common framework for the production and promotion of energy from renewable sources. The Directive commits EU Member States to increase the proportional contribution of renewable sources to EU-wide energy consumption to 20 per cent by 2020. Each Member State has a target for the share of energy generated from renewable sources by 2020; the target for the United Kingdom is 15 per cent.

In its 2010 Energy Policy Statement, '*A low carbon revolution*', the Welsh Government set out aspirations totalling 22.5 Gigawatts of installed capacity from different renewable energy technologies in Wales by 2020/25, including 2 GW from onshore wind and 1 GW from local electricity generation (**National Assembly for Wales, 2013**). As of 2015, there were an estimated 51,303 low carbon energy installations in Wales, with a total capacity of 2,514 MW and saving 4,043,555 t CO_{2e} annual from the energy generated (**Welsh Government, 2015**).

Agricultural production accounts for 12.5% of the total net greenhouse gas emissions from all sources in Wales (**Salisbury *et al*., 2014**). The government has set a target to reduce agricultural and land use emissions to between 4.07 and 4.97 Mt CO2e from a year 2010 baseline of 5.57 Mt CO2e by 2020 (**Welsh Assembly Government, 2010**). One element of a successful climate change strategy is the adoption of on-farm sources of renewable energy, to off-set direct emissions from livestock (enteric methane), emissions from the production of imported energy (fuel and electricity), and those emissions embedded in imported goods (including fertilisers and plant protection chemicals).

This survey recorded the total number of respondent farms with renewable energy installations, and the total capacity or energy generated annually by the installations. Respondents were also asked whether they would consider additional or new installations. All respondents (*n* 601) were included in the analysis.

From the outset it is important to recognise that the scale of renewable installation found on individual farms, if primarily designed to meet household and business needs, will be much lower than found on commercial 'solar farms' or 'wind farms' in Wales that generate power for communities. A typical domestic solar photovoltaic installation will have a rated capacity of around 4 kW and 25 m^2 of panels, whereas the average capacity of solar farms operational in Wales is 8 MW (*n* 61) with around 10 ha of land required for every 5 MW of installation (National Assembly for Wales, 2015). Similarly, a small scale wind turbine intended for an individual household or business, will have a rated capacity up to 50 kW, whereas the individual turbines used by operational on-shore wind farms in Wales have a design capacity up to 3 MW and the average wind farm in Wales has a total capacity of 27 MW (*n* 69) (www.renewables-map.co.uk; 2015). The contribution of on-farm renewable energy production to total renewable energy production in Wales is therefore likely to be limited, although the farms may make an important contribution to off-setting the emissions from agricultural production.

Overall, 28% of survey respondents had some form of renewable energy generation installation on farm (*n* 601; CI 25 to 32%). Installation of renewable energy was not affected by farm type (*fisher exact test*, P>0.10) but was significantly higher on farms participating in the Glastir scheme, at any level (*fisher exact test*, P<0.01). There is no reasons to expect Glastir to have an effect on renewables installation as there is no supportive mechanism, and it is suspected that this effect was an attribute of the type of farm or farm manager entering scheme.

There were a total of 11 farms amongst the respondents that were participating in the Glastir Efficiency Grant (GEG) scheme. The GEG has provided capital grant funding for 157 farms across Wales, to support initiatives that improve resource efficiency and reduce the effects of agriculture on the environment, including greenhouse gases. **Taft *et al*. (2014)** reviewed the approved GEG grants and found that the majority were related to a small number of technologies: rainwater separation (13%); slurry store (12%); new manure store (9%); training shoe or injector system (8%); and new slurry store (8%). Grants are specifically available for energy efficiency, including the purchase of heat recovery units and mechanical wind pumps, but with the exception of a plate heat exchanger in dairy parlours there is no funding for the generation of renewable energy, such as from wind turbines, solar photovoltaic panels or anaerobic digestion. This and the small number of farms in this element of Glastir meant that it was not taken account of in the analysis, and the apparent effect of Glastir participation was not analysed further.

Table 10.1 Percent of all survey respondents with one or more renewable energy installations, stratified by farm type and history of scheme participation (*n* 601).

Scheme History		**DAIRY**	**CS-DA+CS-LOW**	**CS-SDA**
None	None	24 (10 to 37)	13 (5 to 21)	25 (13 to 38)
TC or TG	None	21 (11 to 34)	20 (10 to 32)	26 (14 to 40)
None	GE or GA	38 (19 to 58)	31 (17 to 45)	28 (17 to 40)
TC or TG	GE or GA	44 (30 to 61)	34 (22 to 46)	42 (31 to 53)

Table 10.2 Percent of all survey respondents with specific renewable energy installations, stratified by history of scheme participation (*n* 601).

Scheme History		**Wind Energy**	**Solar Thermal**	**Solar Photovoltaic**	**Hydropower**	**Anaerobic Digestion**	**Biomass Burning**	**Heat Exchanger**
None	None	3 (1 to 7)	7 (3 to 11)	9 (5 to 14)	2 (0 to 5)	1 (0 to 2)	3 (1 to 5)	1 (0 to 2)
TC or TG	None	5 (2 to 9)	5 (2 to 9)	12 (7 to 18)	0 (0 to 0)	<1 (0 to 1)	4 (1 to 7)	2 (0 to 5)
None	GE or GA	5 (2 to 9)	12 (6 to 17)	15 (9 to 22)	2 (0 to 5)	<1 (0 to 1)	7 (3 to 12)	4 (1 to 8)
TC or TG	GE or GA	6 (2 to 9)	7 (3 to 11)	21 (15 to 26)	3 (1 to 6)	<1 (0 to 1)	10 (6 to 14)	5 (2 to 9)
ALL		5 (3 to 7)	8 (5 to 10)	14 (11 to 17)	2 (1 to 3)	<1 (0 to 1)	6 (4 to 8)	3 (2 to 4)

Table 10.3 Percent of all survey respondents without an existing installation and expressing an interest in a type of new renewable energy installation (*n* 231).

Scheme History	**Wind Energy**	**Solar Thermal**	**Solar Photovoltaic**	**Hydropower**	**Anaerobic Digestion**	**Biomass Burning**	**Heat Exchanger**
ALL	59 (53 to 66)	48 (42 to 55)	56 (49 to 62)	28 (23 to 34)	<1 (0 to 1)	29 (23 to 34)	23 (17 to 28)

Table 10.4 Percent of all survey respondents with an existing installation and expressing an interest in a type of additional renewable energy installation (*n* 107).

Scheme History	**Wind Energy**	**Solar Thermal**	**Solar Photovoltaic**	**Hydropower**	**Anaerobic Digestion**	**Biomass Burning**	**Heat Exchanger**
ALL	48 (38 to 57)	31 (22 to 40)	20 (12 to 28)	33 (24 to 41)	<1 (0 to 1)	21 (14 to 28)	20 (12 to 27)

Table 10.1 summarises the percent of all survey respondents with one or more renewable energy installations by farm type, and **Table 10.2** summarises installations by history of scheme participation and type of renewable energy. The most popular installations are of solar photovoltaic and thermal panels. It is believed that the survey response for solar thermal energy is an over-estimate resulting from respondent's confusion with solar photovoltaics. The majority of the respondents are beef cattle and sheep farms, with no need for a hot water supply as used in milking parlours on dairy farms. A survey of dairy farms in Wales by **Promar International Limited (2014)** also recorded relatively few dairy farms investing in solar thermal in comparison to solar photovoltaic.

Promar International Limited (2014) carried out a postal survey of 943 dairy farmers in Wales to collate information on the current structure and production levels in the dairy sector, and the future intentions of farm businesses. The survey reported that 24% of Welsh dairy farms had invested in some form of renewable energy during the previous 5 years, with the majority investing in photovoltaic panels (*c*. 13%) and wind power (*c*. 11%), with few investing in solar thermal (< 5%) or biomass burning (< 5%). A survey of 700 farms from across the United Kingdom reported that 66% of farms generated renewable energy using solar photovoltaics, 30% using wind turbines and 21% by biomass burning (**Farmers Weekly, 2013**). The distribution of renewable energy types is comparable to this survey of Welsh farms.

Table 10.3 and **Table 10.4** summarise respondent interests in additional or new installations by type of renewable energy. Of those farms with an existing installation, 62% expressed an interest in an additional installation, and of those without an existing installation, 53% expressed an interest in a new installation.

Figure 10.1 compares the relative distribution of current number of installations between renewable energy types with the relative distributions of potential new or additional installations. The present bias towards solar photovoltaics decreases substantially for additional installations in favour of wind power or hydropower, indicating a movement towards larger installations, whilst the distribution of potential new installations is more similar to existing installations. **Figure 10.2** and **Table 10.5** summarises the reasons cited by respondents for not considering additional or new renewable energy installations. The most frequent reason was the large capital costs associated with a project.

Table 10.5 Percent of survey respondents citing reasons for not considering installing of new or additional types of renewable energy (*n* 263).

Scheme History	Land availability	Insufficient knowledge	Additional paperwork	Large capital costs	Reliability of supply	Visual impact	Retirement	Tenancy restrictions	Other
ALL	26 (21 to 32)	23 (18 to 28)	27 (21 to 32)	63 (56 to 68)	24 (19 to 30)	34 (29 to 40)	8 (5 to 11)	6 (4 to 10)	14 (11 to 19)

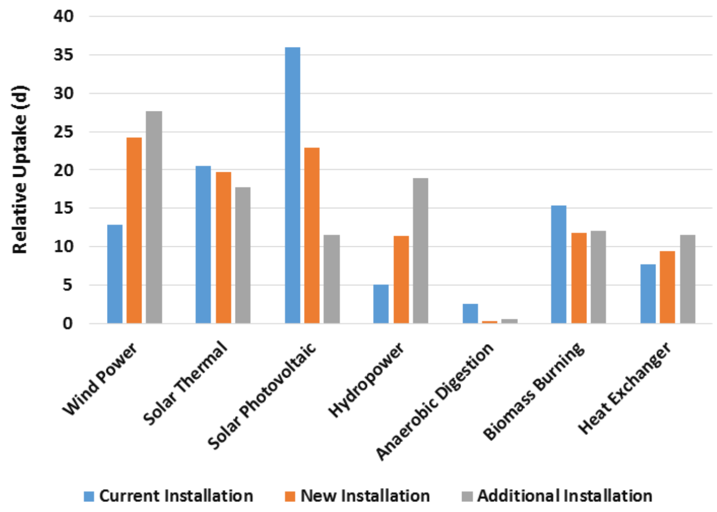


Figure 10.1 Relative distribution of existing and potential additional or new renewable energy installations by type of installation.

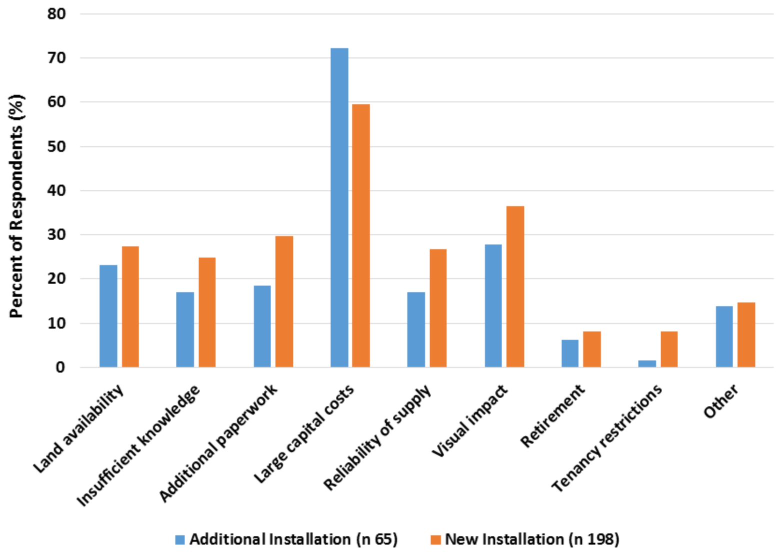


Figure 10.2 Percent of respondents with an existing renewable installation citing reasons for not installing additional capacity, and percent of respondents without an existing installation citing reasons for not installing new capacity.

A proportion of survey respondents were able to report either the energy generated or rated design capacity of the farm installations. Regional load factors for each energy type were used to convert capacity to an estimate of energy generated (**Department for Business, Energy and Industrial Strategy, 2015**; Wind Power 29.5%; Solar Thermal 11.8%; Solar Photovoltaic 11.8%; Hydro Power 41.7%; Anaerobic Digestion, 62.2%; Biomass Burning, 87.2%).

The average quantity of energy currently generated annually on respondent's farms able to provide a value was 47,100 kWh (*n* 50; CI 19,620 to 83,060 kWh), and the average generation capacity on farms able to provide a value was 32.8 kW (*n* 58; CI 22.1 to 45.1 kW).

On respondent's farms with a sole solar photovoltaic installation, the average annual energy generated was 11,880 kWh (*n* 42; CI 4,940 to 21,040 kWh), equivalent to an average capacity of 11.5 kW. Assuming a design capacity of 0.14 kW m^{-2} this would equate to a roof area of 82 m^2 (CAT Solar PV Calculator, 2016). For comparison, **Gallagher *et al*. (2016)** estimated a mean installation capacity of 129 kW for 15 farms in Wales, based on a total feasible roof size of 657 m^2 per farm when making use of all available buildings.

On farms with a sole wind power installation, the average annual energy generated was 157,770 kWh (*n* 8; CI 33,100 to 326,180 kWh). There were an additional 4 respondents that had a wind power installation plus a solar photovoltaic installation and were able to provide either generated or capacity data. Incorporating these into the analysis, the average annual energy generated by a farm with a wind power installation was 114,680 kWh (*n* 12; CI 24,600 to 240,750 kWh), equivalent to an average capacity of 44 kW.

The average capacity value for both solar photovoltaic and wind power is as expected for installations that serve a single household or business.

There are an estimated 10,020 dairy, cattle and sheep farms in Wales above the survey minimum size threshold (Welsh Government, June Agricultural Survey, 2015), compared to a total of 12,380 farms of all types including arable and mixed livestock above the minimum size threshold.

If the reported average quantity of energy currently generated was applicable to all farms with a renewable energy installation, *i.e*. 28% of farms in Wales (above the minimum size threshold), then the national quantity of energy generated annually on farm is calculated as 132,150 MWh. If the same types of renewable energy were installed on all farms expressing an interest in a new installation then the national quantity of energy generated annually on farm could be raised to 311,500 MWh. As **Figure 10.1** shows that new installations would favour wind power, a highly optimistic future scenario is that all farms with renewable energy have a wind turbine with an average capacity of 44 kW (*see above*). This would require relaxation of planning restrictions and external financial incentives, and improvements to the capacity of the local distribution network so that farms could export energy. In this scenario, the national quantity of energy generated annually on farm could be raised to 758,400 MWh, from the 66% of farms that either currently have a renewable energy installation or would consider a new installation.

For consistency with the work of **Gallagher *et al*. (2016)**, the emissions intensity assumed for avoided grid electricity is 0.496 kg CO_2e kW^{-1} based on the energy Solar Energy Calculator (**Energy Saving Trust, 2016**). The on-farm renewable energy generation therefore has the potential to off-set somewhere between a current value of 65,550 t CO_{2e} and optimistic future value of 376,150 t CO_{2e}.

The potential off-set can be compared to an estimate of the national carbon footprint for grazed livestock products in Wales. Annual lamb and beef production are 63,900 t DW and 42,600 t DW respectively (**AHDB, 2015**). **Anthony *et al*. (2012)** used the Bangor University carbon-footprint model (**Taylor *et al*., 2010**) to calculate the average carbon footprint of livestock products for 64 Welsh farms. When expressed over primary products for each farm type, the average footprint for finished lamb at farm gate was 15 kg CO_{2e} kg^{-1} LW and for beef cattle was 14 kg CO_{2e} kg^{-1} LW. Using a killing-out percentage of 47% for lambs and 52% for beef cattle to convert dead-weight to live-weight, the total carbon footprint of lamb and beef production in Wales is calculated as 3,186,300 t CO_{2e} annually.

There are a further 246,000 dairy cattle in Wales (**June Agricultural Survey, 2015**) each providing an average of 7,900 litres of milk annually (**Dairy Industry Statistics, 2016**). The average carbon footprint for milk production is 1.3 kg CO_{2e} l^{-1} (**Anthony *et al*., 2012**), to give a total carbon footprint for all grazing livestock products of 5,712,700 t CO_{2e} annually for Welsh agriculture.

Therefore, current on-farm renewable energy generation is calculated to off-set 1.1% of net greenhouse gas emissions, and a highly optimistic future scenario results in an off-set of 6.6%. It is optimistic as only 5% of farms presently have a wind turbine (**Table 10.2**) and the scenario requires 66% of farms. Only 35% of the survey respondents either had a wind turbine or expressed an interest in wind power.

Anthony *et al*. (2012) reported that on farm electricity accounted for only 1.4% of the total carbon footprint of the 64 surveyed farms, and on farm fuels accounted for an additional 3%. The majority of the footprint is accounted for by enteric methane emissions (41%), nitrous oxide from animal excreta (11%) and embodied in imported fertilisers, agro-chemicals and concentrate feeds (18%). **Taft *et al*. (2014)** similarly calculated carbon footprints for 20 Welsh farms, with 14 revisited following the implementation of GEG technologies. As **Taft *et al.* (2015)** observed, for most farms, only a small percentage (less than 4.4%) of net emissions were attributable to electricity use in the baseline study, and the findings were similar for re-visited farms. The potential to off-set the farm carbon footprint is therefore also limited by the direct contribution from on farm electricity use. A movement away from solar photovoltaics towards wind power would increase the potential for on farm renewable energy generation, providing that planning issues can be resolved and a majority of farms are connected to the national grid.

Overall, 28% of surveyed grazing livestock farms generated some form of renewable energy, generally from solar photovoltaic installations, each with an average capacity of 33 kW. Current capacity is sufficient to off-set an estimated 1% of net greenhouse gas emissions from agriculture. There is the potential to raise this to circa 5% of farm emissions, with the wide spread installation of wind turbines, 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,.

11. Farm Resilience

Hypothesis*: participation in agri-environment schemes supports farm management activity to adapt to climate change threats and to improve the farm business.*

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. Relevant business strategies are large in number, and include enterprise diversification and insurance against future yields and prices, the introduction of drought resistant crop varieties and livestock with improved genetic merit, biosecurity measures to prevent the transmission of bovine tuberculosis, seasonal risk assessment and preventative veterinary treatments for nematodirosis and gastro-enteritis in lambs and liver flukes in ewes, provision of shade for livestock and planning forage production for extended housing periods, and seeking production and efficiency gains through the introduction of new machinery and practices. Resilience relies heavily on the skills and enterprise of individual farm managers, but it is hypothesised that the knowledge, financial and organisational support provided through participation in an agri-environment scheme may advance the implementation of relevant strategies. Note that the emphasis here is on adaptation to the effects of climate change and not the mitigation of change by control of greenhouse gas emissions, although efficiency gains may achieve both.

The general need to improve business resilience and thereby the sustainability of British agriculture is especially true of the grazing livestock farm types in Wales. The **Wales Rural Observatory (2013)** carried out an income analysis of farms in Wales as part of a review of the Community Agricultural Policy. Overall, 46% of interviewed farms were in profit, 29% at a loss, and 20% at break-even in the survey year (*n* 2402). The **Commission for Rural Communities (2010)** provided a definition of a sustainable farming livelihood: *farms achieving a household income above the relative poverty threshold, and a positive farm business income, and a positive total income from farming*. The relative poverty threshold is defined as 60% of median national income. Median national income in the United Kingdom in 2010 was £19,500 before tax (**Her Majesty's Revenue and Customs, 2012**). Using records from the Farm Business Survey, averaged over the period 2006 to 2010, **Anthony *et al*. (2016)** calculated that between 15 and 30**%** of dairy, between 11 and 39% of lowland cattle and sheep, and between 50 and 65% of Less Favoured Area cattle and sheep farms in Wales, decreasing with farm size, failed to achieve a sustainable farming livelihood each year. An analysis of records from the **Farm Business Survey (Hoult, 2009)** also summarised the consistency of performance quartiles over time, defined as the ratio of outputs over inputs, for four years in the period 2005 to 2008. Overall, 64% of dairy farms were in the same quartile for three or more years, with 30% remaining in the top quartile and 12% remaining in the bottom quartile (*n* 158). Similarly, for Less Favoured Area cattle and sheep farms, 69% were in the same quartile for three or more years, with 19% remaining in the top quartile and 25% remaining in the bottom quartile (*n* 161). Whilst there is some consistency in relative farm business performance, 53% of dairy farms and 40% of cattle and sheep farms spent at least one year in the top quartile, and 39% of dairy farms and 41% of cattle and sheep farms spent at least one year in the bottom quartile, indicative of fluctuating performance.

The Wales Rural Observatory (2010) derived measures of resilience and vulnerability based on responses to open-ended questions on intentions following a reduction in government payments to farmers or rising input costs and falling farm gate prices. Farms were coded as vulnerable if they intended to de-intensify, exit from farming or carry on business as usual, and resilient if they intended to cut costs, diversity, intensify or farm more environmentally. Overall, between 64 and 71% of the grazing livestock farm types were codes as vulnerable in the context of falling government payments, and between 70 and 80% in the context of rising costs and falling sale prices. Vulnerability tended to increase with age of farmer, and decrease with farm size and household income. The survey found that farming households that were unlikely to join the Glastir scheme tended to be vulnerable, and those that were more aware of Glastir were more resilient **(Wales Rural Observatory, 2010)**.

The United Kingdom Climate Change Risk Assessment 2017, summary for Wales, projects an increase in summer temperatures by between 0.9 and 4.5 ^{o}C by the 2050s compared to the 1961 to 1990 baseline under a medium emissions scenario, and a regional increase in winter precipitation totals between -2 and 31% (**Committee on Climate Change, 2016**). The principal perceived threats are increased frequency of drought and flooding, but livestock may also be affected by heat stress, higher spring rainfall may delay livestock turn-out and increase rates of soil erosion, and there may be some impact on the prevalence of pests and diseases. The Farming Futures survey of 400 farms in England reported that 40% of sheep farms, 36% of beef cattle and 31% of dairy farms believed that climate change presented greater risks than opportunities for their business (**Farming Futures, 2011**). The majority of respondents cited unpredictable weather (43%), flooding (20%) and droughts (17%) as climate change threats. Overall, 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. In general, most farmers are reactive to recent weather events and not proactive in terms of adaptation to future climate change (**Gill, 2013**).

This survey asked respondents whether they had taken a specific action to help adapt to a climate change threat, or to improve aspects of the farm business. Where action had been taken, respondents were asked whether membership of the Glastir scheme had helped in any way. The survey design did not allow for the specific actions to be recorded.

Climate Change

Table 11.1 summarises the average total number of climate threats that respondents claimed to have taken action on in the past three years, and the percent of respondents taking action to adapt to specific threats. Whilst the overall average was *circa* one action per respondent, a high percentage of respondents took no action to adapt to climate change threats (58%) whilst others took multiple actions. The percent of respondents taking no action was significantly higher on the CS-DA+CS-LOW (61%) and CS-SDA (66%) in comparison to the DAIRY (41%) farm type (*fisher exact test*, $P<0.05$).

Between 7 and 36% of respondents had taken action on specific climate change threats, and the survey results are similar to those for an earlier survey of farms in England. The exception being that 36% of dairy farms and 18% of cattle and sheep farms in this survey of Welsh farmers reported having taken action on heat stress in livestock. The Farm Practices Survey for England (**Defra, 2008**), reported that up to 15% of dairy farms and 8% of cattle and sheep farms has taken action to adapt to increased risk of flooding, drought, soil erosion or heat stress. Only 5% had taken action on biodiversity but 22% of dairy farms and 27% of cattle and sheep farms claimed to have taken action on pests and diseases.

Statistical modelling found that the prevalence of action on flood and drought risk, and on the increased threat of pest and disease, did not differ between farm types or with history or scheme participation. However, both the total number of actions and percent of respondents carrying out action on soil erosion and heat stress on livestock were significantly lower on CS-SDA and CS-DA+CS-LOW farms in comparison to the DAIRY farm type (*generalised linear model*, $P<0.05$). In general, cattle and sheep farms carried out 0.40 fewer total actions and the percent carrying out a specific action was between 10 and 17% lower (**Table 11.2**).

Participation in the Glastir scheme was associated with a significantly higher total number of actions and percent of respondents carrying out action on soil erosion and biodiversity. Participants in Glastir carried out 0.35 more total actions and the percent carrying out a specific action was between 8 and 12% higher (**Table 11.2**).

Table 11.1 Average count of all actions taken to adapt to the climate change threats, and the percent of farms taking action to adapt to specific threats, stratified by farm type (*n* 508).

	DAIRY	CS-DA+CS-LOW	CS-SDA
Count of all actions (n)	1.2 (0.9 to 1.4)	0.8 (0.6 to 0.9)	0.8 (0.6 to 1.1)
Increased frequency of flooding (%)	9 (4 to 15)	9 (5 to 13)	11 (7 to 16)
Increased frequency of drought (%)	9 (5 to 14)	7 (4 to 10)	8 (4 to 12)
Increased rates of soil erosion (%)	22 (15 to 30)	13 (9 to 18)	12 (8 to 17)
Loss of biodiversity (%)	13 (7 to 19)	12 (8 to 16)	10 (6 to 15)
Increased threat of pest and disease (%)	27 (19 to 36)	18 (13 to 24)	23 (17 to 29)
Heat stress on livestock (%)	36 (27 to 44)	17 (12 to 22)	19 (13 to 25)

Tables 11.3 to 11.6 summarise the count of actions and uptake of specific actions by farm type and history of scheme participation. The absence of an effect of participation in the preceding Tir Cynnal or Tir Gofal schemes lends weight to the effect of Glastir, rather than an effect of the type of farm or farm manager entering an agri-environment scheme.

Overall, 70% of respondents who had taken one or more actions to adapt to climate change and were participating in the Glastir scheme acknowledged some form of support provided by the scheme. **Figure 11.1** summarises the percent of respondents who acknowledged support for the Entry and Advanced levels. The type of support did not vary significantly with the scheme level (*fisher exact test*, $P>0.10$). A majority of respondents (72%) cited that the

Glastir scheme provided them with relevant information. Participation in Glastir also encouraged farm managers to bring forward an action already planned (56%) and provided financial support (53%). It is of interest to note that 29% of respondents also cited that participation in scheme encouraged collaboration with other farms (**Table 11.7**).

Table 11.2 Coefficients and marginal effects of poisson and binomial models fitted to the total count of actions taken to adapt to climate change threats, and the proportion of respondents taking action to adapt to specific threats (*n* 508).

Poisson Model Coefficients and Marginal Effects					
Total Count of Actions	**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-0.01084	0.09562	-0.113	>0.10
	IS_CS	-0.41979	0.10307	-4.073	<0.01
	IS_GEGA	0.3974	0.09514	4.177	<0.01
	AIC:	1460.4			
	Marginal Effect	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.402807	0.109769	-3.6696	<0.01
	IS_GEGA	0.349702	0.085442	4.0929	<0.01
Binomial Model Coefficients and Marginal Effects					
Soil Erosion	**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-1.5324	0.2512	-6.099	< 0.01
	IS_CS	-0.7574	0.2743	-2.762	< 0.01
	IS_GEGA	0.6736	0.2565	2.626	< 0.01
	AIC:	418.32			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.10491	0.042393	-2.4747	< 0.05
	IS_GEGA	0.083749	0.032347	2.5891	< 0.01
Biodiversity	**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-2.7689	0.25	-11.075	< 0.01
	IS_GEGA	1.2951	0.3041	4.258	< 0.01
	AIC:	344.79			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_GEGA	0.12734	0.0297	4.2874	< 0.01
Heat Stress on Livestock	**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	(Intercept)	-0.5931	0.1923	-3.085	< 0.01
	IS_CS	-0.9268	0.2332	-3.974	< 0.01
	AIC:	524.73			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.17644	0.04817	-3.6629	< 0.01

Table 11.3 Average count of all actions taken to adapt to climate change threats, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	1.1 (0.7 to 1.5)	0.7 (0.5 to 1.0)	0.7 (0.3 to 1.1)
TC or TG	None	1.0 (0.6 to 1.4)	0.5 (0.3 to 0.8)	0.7 (0.3 to 1.1)
None	GE or GA	1.4 (0.8 to 2.1)	0.6 (0.3 to 1.1)	1.1 (0.7 to 1.5)
TC or TG	GE or GA	1.4 (0.9 to 2.0)	1.3 (0.8 to 1.7)	0.9 (0.5 to 1.4)

Table 11.4 Average percent of farms taking action to adapt to increased rates of soil erosion under climate change, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	24.4 (12.2 to 36.6)	13.1 (4.9 to 23.0)	4.2 (0.0 to 10.4)
TC or TG	None	11.4 (2.9 to 22.9)	7.3 (1.8 to 14.5)	10.4 (2.1 to 20.8)
None	GE or GA	26.3 (10.5 to 47.4)	16.2 (5.4 to 29.7)	14.9 (6.4 to 25.5)
TC or TG	GE or GA	30.4 (13.0 to 52.2)	18.2 (6.8 to 29.6)	18.0 (8.0 to 28.0)

Table 11.5 Average percent of farms taking action to adapt to loss of biodiversity under climate change, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	2.4 (0.0 to 7.3)	6.6 (1.6 to 13.1)	8.3 (2.1 to 16.7)
TC or TG	None	11.4 (2.9 to 22.9)	1.8 (0.0 to 5.5)	6.3 (0.0 to 14.6)
None	GE or GA	26.3 (10.4 to 47.4)	16.2 (5.4 to 27.0)	10.6 (2.1 to 19.1)
TC or TG	GE or GA	21.7 (8.7 to 39.1)	27.3 (15.9 to 40.9)	16.0 (6.0 to 28.0)

Table 11.6 Average percent of farms taking action to adapt to heat stress on livestock under climate change, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	29.3 (17.1 to 43.9)	19.7 (9.8 to 29.5)	16.7 (8.3 to 29.2)
TC or TG	None	34.3 (20.0 to 51.4)	12.7 (5.5 to 21.8)	16.7 (6.3 to 27.1)
None	GE or GA	47.4 (26.3 to 68.4)	8.1 (0.0 to 16.2)	27.7 (14.9 to 40.4)
TC or TG	GE or GA	39.1 (21.6 to 60.9)	25.0 (13.6 to 38.6)	16.0 (6.0 to 26.0)

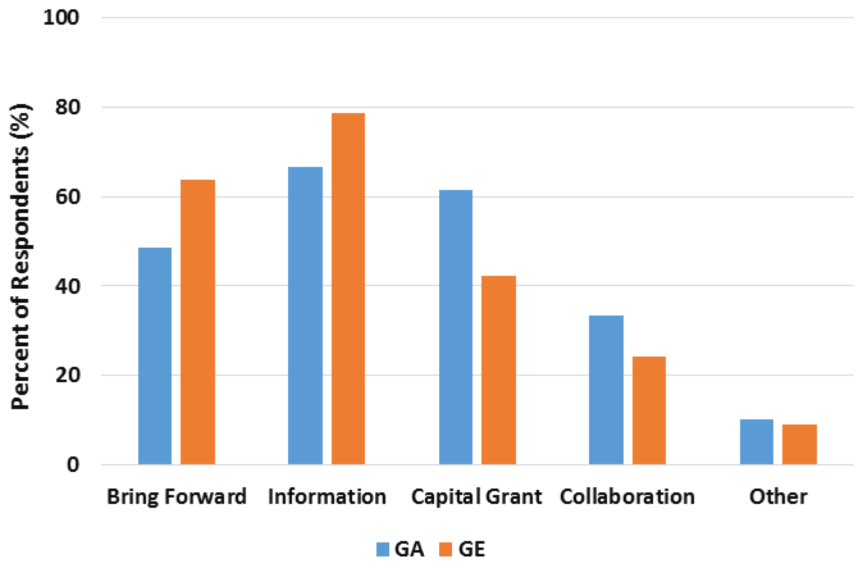


Figure 11.1 Percent of respondents who had taken action to adapt to climate change threats and acknowledged the support of the Glastir scheme that cited specific types of support, stratified by scheme level (*n* 103).

Table 11.7 Percent of respondents who had taken action to adapt to climate change threats and acknowledged the support of the Glastir scheme that cited specific types of support (*n* 103).

Type of Support	Percent of Respondents
Encouraged farm to bring forward an action already planned	56
Provided farm with information	72
Provided a grant for capital investment	53
Encouraged collaboration with other farms	29
Other	10

Business Improvement

Table 11.8 summarises the average total number of actions taken to improve the farm business, and the percent of respondents taking action to improve specific aspects. The overall average number of actions was higher than for climate change, and the percentage of respondents taking no action to improve the farm business (33%) was also lower than for climate change threats. The percent of respondents taking no action was significantly higher on the CS-DA+CS-LOW (22%) and CS-SDA (32%) in comparison to the DAIRY (11%) farm type (*fisher exact test*, $P<0.05$).

Table 11.8 Average count of all actions taken to improve the farm business, and the percent of farms taking action on specific aspects, stratified by farm type (*n* 508).

	DAIRY	CS-DA+CS-LOW	CS-SDA
Count of all actions (n)	2.7 (2.4 to 3.0)	1.9 (1.7 to 2.1)	1.7 (1.5 to 1.9)
Fuel and energy efficiency (%)	59 (51 to 68)	28 (22 to 35)	28 (22 to 35)
Nutrient efficiency (%)	62 (53 to 71)	35 (28 to 42)	29 (22 to 36)
Animal health (%)	79 (71 to 86)	66 (60 to 73)	57 (51 to 64)
Business diversification (%)	23 (15 to 31)	22 (16 to 28)	24 (18 to 30)
Water use efficiency (%)	51 (42 to 59)	39 (32 to 45)	29 (23 to 36)

Between 22 and 79% of respondents had taken action on specific improvements to the farm business. Greatest action was taken to improve animal health, and least for business diversification (**Table 11.8**). The number taking action and the areas of improvement are broadly similar to that reported by the survey of Farmer's Intentions for livestock farms in England (**Farm Business Survey, 2016**). Respondents to the English survey reported the introduction of a new practice or innovation. Around 27% of businesses had introduced a new practice in the previous year. Overall, intentions survey reported that 9% of businesses had introduced a new practice or innovation linked to renewable energy or water conservation, including the adoption of solar panels or rain water harvested; 17% linked to livestock husbandry, including disease screening and paddock grazing; 39% linked to business practice, including contract rearing and change in breed of sheep; and 44% linked to the use of specialist equipment, including use of a sward lifter and employment of electronic identification (**Farm Business Survey, 2016**).

Statistical modelling found that there was an effect of farm type or scheme participation on the prevalence of all actions to improve the farm business. The total number of actions carried out was significantly lower on CS-SA and CS-DA+CS-LOW farms in comparison to the DAIRY farm type (*generalised linear model*, P<0.01). In general, cattle and sheep farms carried out 1.0 fewer total actions (**Table 11.9**). There was no effect of farm type on business diversification, but the percent carrying out a specific action to improve fuel efficiency, nutrient efficiency, animal health and water use efficiency was between 17 and 35% lower on the cattle and sheep farm types.

The total number of actions carried out to improve the farm business was significantly higher on farms participating in Glastir (*generalised linear model*, P<0.01). In general, farms in Glastir carried out 0.34 more total actions (**Table 11.9**). There was no effect of scheme participation on fuel efficiency, animal health, or water use efficiency. The percent carrying out specific actions to improve nutrient efficiency and business diversification was significantly higher by between 13 and 17% (**Table 11.9**).

Tables 11.10 to 11.15 summarise the count of actions and uptake of specific actions by farm type and history of scheme participation. Once again, the absence of an effect of participation in the preceding Tir Cynnal or Tir Gofal schemes lends weight to the effect of

Glastir, rather than an effect of the type of farm or farm manager entering an agri-environment scheme. The affected business areas can be directly related to scheme requirements.

Overall, 55% of respondents who had taken one or more actions to improve the farm business and were participating in the Glastir scheme acknowledged some type of scheme support. **Figure 11.2** summarises the percent of respondents who acknowledge support for the Entry and Advanced levels. The percent of respondents acknowledging financial support was significantly higher for the Advanced scheme level (*fisher exact test*, $P<0.01$).

The majority of respondents (77%) again cited that the Glastir scheme provided them with relevant information, encourages them to bring forward an action already planned (60%) and provided financial support (57%) (**Table 11.16**).

Based on self-reporting of activity there is evidence that farms participating in the Glastir scheme had carried out a greater number of diverse actions to adapt to climate change, specifically relating to soil and biodiversity management, nutrient efficiency and business diversification. A majority of participants acknowledge the support provided by the scheme, citing the provision of relevant information and encouragement to bring forward actions that had already been planned, in addition to financial support.

Table 11.9 Coefficients and marginal effects of poisson and binomial models fitted to the total count of actions taken to improve the farm business, and the proportion of respondents taking action on specific aspects (*n* 508).

Poisson Model Coefficients and Marginal Effects					
	Model Coefficient	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
Total Count of Actions	(Intercept)	0.9431	0.06098	15.466	<0.01
	IS_CS	-0.44221	0.06761	-6.541	<0.01
	IS_GEGA	0.17	0.06303	2.697	<0.01
	AIC:	1829.4			
	Marginal Effect	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.98785	0.16842	-5.8653	<0.01
	IS_GEGA	0.33887	0.12693	2.6697	<0.01
Binomial Model Coefficients and Marginal Effects					
	Model Coefficient	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
Fuel Efficiency	(Intercept)	0.3773	0.1874	2.013	<0.05
	IS_CS	-1.299	0.2184	-5.947	<0.01
	AIC:	629.32			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.30861	0.050666	-6.0909	<0.01
	Model Coefficient	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
Nutrient Efficiency	(Intercept)	0.2975	0.2008	1.481	>0.10
	IS_CS	-1.3126	0.2229	-5.888	<0.01
	IS_GEGA	0.5486	0.1929	2.844	<0.01
	AIC:	643.95			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.3158	0.050989	-6.1935	<0.01
	IS_GEGA	0.130136	0.045544	2.8574	<0.01
	Model Coefficient	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
Animal Health	(Intercept)	1.3137	0.2253	5.831	<0.01
	IS_CS	-0.8329	0.2482	-3.355	<0.01
	AIC:	644.62			
	Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
	IS_CS	-0.17019	0.044949	-3.7862	<0.01

Table 11.9 *cont*. Coefficients and marginal effects of poisson and binomial models fitted to the total count of actions taken to improve the farm business, and the proportion of respondents taking action on specific aspects (*n* 508).

Binomial Model Coefficients and Marginal Effects						
Business Diversification		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	-1.458	0.1291	-11.296	<0.01
		IS_GA	0.8916	0.2323	3.837	<0.01
		AIC:	535.67			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		IS_GA	0.173293	0.048804	3.5508	<0.01
Water Use Efficiency		**Model Coefficient**	**Estimate**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		(Intercept)	0.0339	0.1841	0.184	>0.10
		IS_CS-DA+CS-LOW	-0.499	0.2352	-2.121	<0.05
		IS_CS-SDA	-0.9285	0.243	-3.821	<0.01
		AIC:	664.76			
		Marginal Effect	**dF/dx**	**Std. Error**	**Z Value**	**Pr(>|z|)**
		IS_CS-DA+CS-LOW	-0.11473	0.052852	-2.1707	<0.05
		IS_CS-SDA	-0.20822	0.05123	-4.0643	<0.01

Table 11.10 Average count of all actions taken to improve the farm business, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	2.4 (1.9 to 3.0)	1.7 (1.4 to 2.1)	1.4 (1.0 to 1.9)
TC or TG	None	2.8 (2.4 to 3.2)	1.7 (1.4 to 2.1)	1.7 (1.3 to 2.2)
None	GE or GA	3.1 (2.5 to 3.6)	2.1 (1.6 to 2.6)	1.8 (1.4 to 2.2)
TC or TG	GE or GA	3.0 (2.3 to 3.6)	2.2 (1.8 to 2.7)	1.8 (1.3 to 2.2)

Table 11.11 Average percent of farms taking action to improve fuel and energy efficiency, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	53.7 (39.0 to 68.3)	27.9 (16.4 to 39.3)	18.8 (8.3 to 31.3)
TC or TG	None	60.0 (42.9 to 77.1)	23.6 (12.7 to 34.5)	31.3 (18.8 to 45.8)
None	GE or GA	68.4 (47.4 to 89.5)	27.0 (13.5 to 40.5)	29.8 (17.0 to 44.7)
TC or TG	GE or GA	60.9 (43.5 to 82.6)	36.4 (22.7 to 50.0)	34.0 (22.0 to 48.0)

Table 11.12 Average percent of farms taking action to adapt to improve nutrient efficiency, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	51.2 (36.6 to 65.9)	29.5 (19.7 to 41.0)	20.8 (10.4 to 33.3)
TC or TG	None	62.9 (45.7 to 77.1)	25.5 (14.5 to 38.2)	31.3 (18.8 to 43.8)
None	GE or GA	73.7 (52.6 to 89.5)	43.2 (27.0 to 59.5)	29.8 (17.0 to 42.6)
TC or TG	GE or GA	69.6 (52.2 to 87.0)	47.7 (34.1 to 63.6)	34.0 (20.0 to 48.0)

Table 11.13 Average percent of farms taking action to adapt to improve animal health, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	73.2 (58.5 to 87.8)	63.9 (52.5 to 77.0)	50.0 (37.5 to 64.6)
TC or TG	None	85.7 (74.3 to 97.1)	67.3 (52.7 to 78.2)	58.3 (43.8 to 70.8)
None	GE or GA	78.9 (57.9 to 94.7)	59.5 (43.2 to 75.7)	63.8 (48.9 to 76.6)
TC or TG	GE or GA	78.3 (60.9 to 91.3)	75.0 (61.4 to 86.4)	56.0 (42.0 to 70.0)

Table 11.14 Average percent of farms taking action to adapt to diversify the farm business, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	19.5 (7.3 to 34.1)	19.7 (9.8 to 29.5)	20.8 (10.4 to 33.3)
TC or TG	None	22.9 (11.4 to 37.1)	16.4 (7.3 to 25.5)	20.8 (10.4 to 33.3)
None	GE or GA	21.1 (5.3 to 37.0)	32.4 (18.9 to 48.6)	25.5 (14.9 to 38.4)
TC or TG	GE or GA	30.4 (13.0 to 47.8)	22.7 (11.4 to 34.1)	28.0 (16.0 to 40.0)

Table 11.15 Average percent of farms taking action to adapt to improve water use efficiency, stratified by farm type and history of scheme participation (*n* 508).

Scheme History		DAIRY	CS-DA+CS-LOW	CS-SDA
None	None	43.9 (29.3 to 58.5)	32.8 (21.3 to 44.3)	29.2 (16.7 to 41.7)
TC or TG	None	48.6 (31.4 to 65.7)	38.2 (25.5 to 50.9)	27.1 (14.6 to 39.6)
None	GE or GA	63.2 (36.8 to 84.2)	48.6 (32.4 to 64.9)	31.9 (19.1 to 46.8)
TC or TG	GE or GA	56.5 (39.1 to 78.3)	38.6 (24.9 to 52.3)	28.0 (16.0 to 40.1)

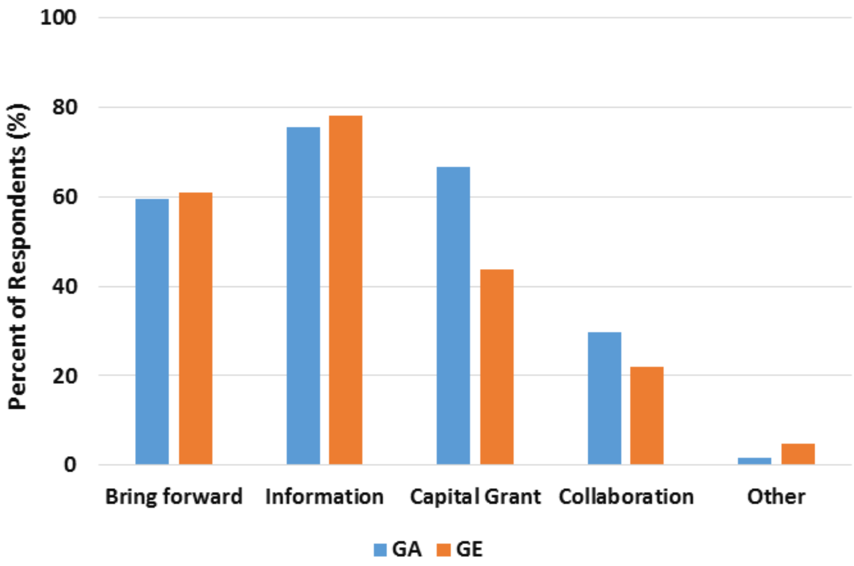


Figure 11.2 Percent of respondents who had taken action to improve the farm business and acknowledged the support of the Glastir scheme that cited specific types of support, stratified by scheme level (*n* 177).

Table 11.16 Percent of respondents who had taken action to improve the farm business and acknowledged the support of the Glastir scheme that cited specific types of support (*n* 177).

Type of Support	Percent of Respondents
Encouraged farm to bring forward an action already planned	60
Provided farm with information	77
Provided a grant for capital investment	57
Encouraged collaboration with other farms	27
Other	3

12. Management Change

Hypothesis*: participation in agri-environment schemes results in a change in farm management and thereby the health of the farm business and environment quality, that may in turn affect interest in the public benefits of farming.*

Increase in farm revenue is the most frequently cited motivation for participation in agri-environment schemes, and farmers who adopt more complex scheme options are more likely to do so for financial reasons (**van Herzele, 2013**). However, it is also generally believed that a majority of farm managers will not change their practices and management strategies to participate in agri-environment schemes. A farm system that already fits with scheme specifications, *i.e.* of relatively low intensity and with management responsibility for already existing and relevant habitat, is seen to be essential to scheme participation and often used to explain the relatively low participation by dairy farms (**Rural Observatory for Wales, 2011**). This fits with the general observation that farms in areas with lower agricultural production potential and with extensive livestock management are more likely to participate (**Hynes and Garvey, 2009; Lastro-Bravo *et al*. 2015; Dupraz *et al*., 2002**). **Ingram *et al*. (2009)** in a review of farm entry and exit from agri-environment schemes in Wales found that there were many different types of motivation due to the heterogeneity of farms and farmers, but these were in most part linked to farm capacity. Capital payments and fitting in with the farm system were key factors in determining scheme uptake.

It is therefore of policy interest to establish whether participation in the Glastir scheme resulted in any change of farm management, and in turn whether a change of management is correlated with positive outcomes for the farm business and environment.

This survey recorded farm managers' own assessment of management change and perceived farm outcomes by eliciting a score for the degree of agreement or disagreement with statements asserting that change had occurred. For farms previously in the Tir Cynnal or Tir Gofal schemes that had come to an end, but not currently enrolled in the Glastir scheme, the statements were written to assess whether lasting change had occurred.

It is recognised that asking farmers for their own assessment of change risks a response that is based on the information and expectations that they have been alerted to through contact with scheme advisors and literature, rather than real change that has occurred on the farm. It is also possible that farmers who report a high degree of management change are likely to report an expected degree of change in the physical environment due to their efforts, rather than the actual degree of change. However, we choose to trust the responses provided for this analysis, and their information content is provided some support by a comparison with responses from the first farm practices survey for Wales (**Anthony *et al*., 2012**).

Both this and the first survey asked respondents to score the extent to which they agreed that participation in an agri-environment scheme had "*changed my management of the* *farm*". This was asked of participants in the Tir Cynnal and Tir Gofal schemes in the first survey, and of participants in Glastir in this second survey.

In comparison to the preceding schemes, significantly fewer respondents agreed that there had been a change in farm management in this survey under Glastir (*fisher exact test*, P<0.0). 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 12.1 and Figure 12.1**). The response by the Glastir participants was unaffected by the any history of participation in the previous schemes (**Figure 12.2**), supporting the conclusion that the Glastir scheme is genuinely perceived to have resulted in less change in farm management than the preceding schemes. This concurs with our own opinion that the previous schemes that demanded completion of a farm resource management plans were more demanding at the time of first entry, and that the community perception of Glastir having lower return-on-effort in comparison to Tir Gofal has likely resulted in farms entering scheme that required fewer changes to existing management.

Table 12.1 Percent distribution of Likert scores for agreement with a *'changed my management of the farm*' on farms participating in the Glastir Scheme (2nd WFPS - this survey) or having participated in the Tir Cynnal or Tir Gofal schemes (1st 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

Analyses of the farm records used to construct the sample pool for this survey revealed that participation in the Tir Gofal and Glastir schemes generally increased with farm size, and is highest on the CS-SDA farm type (**Tables 12.2 and 12.3**). The latter generally have a greater area of relevant habitat, and a lower overall stocking rate and fertiliser inputs (**Anthony and Stopps, 2016**), that may correlate with a lower requirement for management change. The increased level of participation for CS-SDA farms may in part be related to the ending of the Tir Mynydd scheme that made payments to farms in marginal areas. Payments were made to beef cattle and sheep farms within the Severely Disadvantaged Area and the Disadvantaged Area of the Less Favoured Area. At the close of the scheme in 2012, all farms within the Less Favoured Area, including dairy farms, participating in the Glastir scheme were eligible for an uplift to their Entry level payments.

Farmer attitude may also have a role in explaining the variation in scheme uptake, and the associated level of management change. A farmer segmentation model was recently developed by Brook-Lyndhurst for Welsh Government (**Woolf *et al*., 2016**), and it has been applied by **Cao and Elliott (2015)** in an investigation of the reasons behind the uptake or non-uptake of Glastir Woodlands Element grants or grants from preceding schemes such as

Better Woodlands for Wales. There are five segment types, each representing between 11 and 35% of all farms (**Table 12.4**). **Cao and Elliott (2015)** simplify the segments as varying across two dimensions of 'openness' (acquiring new technology, knowledge or skills) and 'productivist' (prioritising income generation over a good quality of life and wider environmental concerns) leanings. A large number of farms have been assigned to segments by the surveys of Cao and Elliott (*n* 1005) and Woolf *et al*. (*n* 1814) and it is recommended that future work attempt to match the respondents from this survey and investigate whether segment can contribute to explaining the variation in responses presented below.

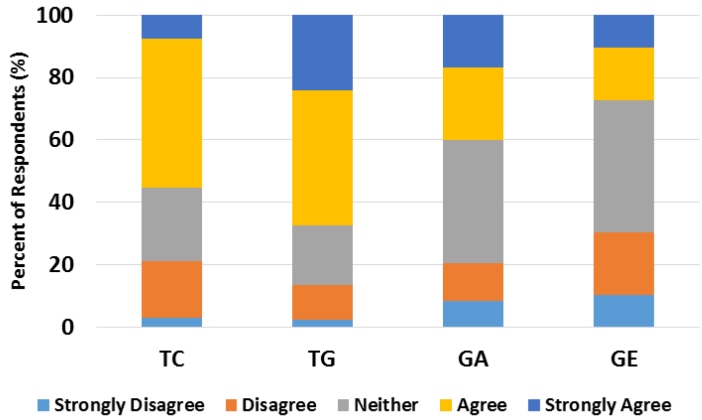


Figure 12.1 Cumulative percent of 1st and 2nd Wales Farm Practice Survey respondents agreeing with the statement that participation in an agri-environment scheme had 'changed my management of the farm', stratified by scheme: Tir Cynnal (TC); Tir Gofal (TG); Glastir Entry (GE); and Glastir Advanced (GA).

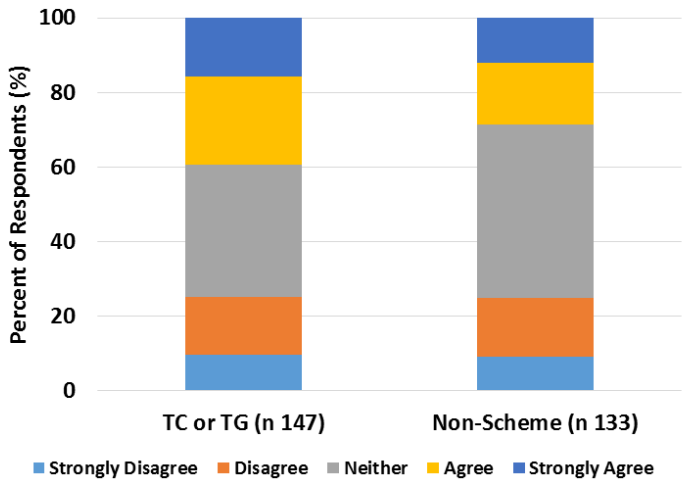


Figure 12.2 Cumulative percent of 2nd Wales Farm Practice Survey respondents agreeing with the statement that participation in the Glastir scheme had 'changed my management of the farm', stratified by history of participation in the preceding Tir Cynnal or Tir Gofal schemes.

The analysis of results from this survey was restricted to farms currently participating in at least one of the Entry or Advanced levels of the Glastir scheme (*n* 280), regardless of any other Glastir element, and those that had exclusively participated in either of the preceding Tir Cynnal or Tir Gofal schemes but had not applied for Glastir (*n* 138) and are referred as having exited scheme.

Management Change

Figure 12.3 graphs the average Likert score for each of the assessed statements. In general, average scores were higher for farms in the upper level of a scheme (Tir Gofal versus Tir Cynnal; and Glastir Advanced versus Glastir Entry) and for farms currently in Glastir compared to farms that had exited the previous Tir Cynnal or Tir Gofal schemes. The latter was expected as the assessment was of the *current effect* of Glastir participation rather than of a *lasting effect* for Tir Cynnal or Tir Gofal.

Survey respondents self-assessed the extent of farm management change resulting from scheme participation using a Likert scale, ranging from 1 for strong disagreement to 5 for strong agreement with the statement that participation in scheme had '*changed my management of the farm*.' Overall, 25% of farms currently participating in the Glastir scheme disagreed or strongly disagreed with the statement, and 36% of farms exiting the previous Tir Cynnal or Tir Gofal schemes. The percent agreeing with the statement were a very similar 26% and 35% respectively (**Table 12.5**). **Figures 12.4** and **12.5** shows the cumulative distribution of Likert scores for each scheme history.

The average Likert scores for farms participating in Glastir were significantly lower on farms with a dairy herd, and on farms participating in the Commons element of the scheme (*ordinal regression*, P<0.05). The lower level of effort on the dairy farms was contrary to expectation with respect to intensity of production and availability of habitat, and this may therefore in part reflect the amendments to the Glastir scheme entry requirements in an attempt to encourage participation by dairy farms. There was no effect of farm size, stocking density or area of woodland and rough grazing used as proxy indicators for intensity of production (*ordinal regression*, P>0.10). Participation in the higher level Glastir Advanced scheme also resulted in an increase in the average Likert score (*kruskal-wallis*, P<0.05) relative to Glastir Entry.

Similarly, for farms that had exited the Tir Cynnal or Tir Gofal schemes but were not participating in Glastir, the Likert scores were unaffected by proxy indicators of production intensity (*ordinal regression*, P>0.10), and the average score increased with participation in the higher level Tir Gofal scheme (*kruskal-wallis*, P<0.05) relative to Tir Cynnal. There was no effect of farm type.

The average Likert scores for agreement with the statement that scheme participation '*changed my management of my farm*' on farms in the current Glastir scheme were higher (Glastir Entry 3.0; Glastir Advanced 3.3) than for farms that had exited the previous schemes (Tir Cynnal 2.6; Tir Gofal 3.0) (*kruskal-wallis*, P<0.05). The variation in self-assessed level of management change may be associated with the specific scheme options taken up, and it is recommended that future work attempt to link government scheme records with this survey for a more detailed analysis.

Perceived Outcomes

Survey respondents scored perceived outcomes from scheme participation, also using a Likert scale. The outcomes were organised into pairs: a) 'i*mproved 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. Factor analysis was used to establish that there were indeed three dimensions to the perceived outcome scores (*factor analysis*, P<0.01). The polychoric correlation coefficients for each pair of outcome scores were in the range 0.65 to 0.72 for farms currently in Glastir and in the range 0.67 to 0.74 for farms exiting the Tir Cynnal or Tir Gofal scheme (**Olsson, 1979**). The Cronbach alpha coefficients for each pair were in the range 0.74 to 0.80 for farms currently in Glastir and in the range 0.77 to 0.81 for farms exiting the Tir Cynnal or Tir Gofal scheme (**Eisinga *et al*., 2012**).

The percent of respondents who disagreed or strongly disagreed with statements that scheme participation had a positive impact on outcomes varied from 17 to 40% for farms currently in Glastir and from 26 to 49% for farms having exited Tir Cynnal or Tir Gofal. The extent of disagreement was significantly lower for the '*enhanced the plants and wildlife on my farm*' and '*improved the appearance of my farm*' outcomes (**Tables 12.7 and 12.8**) (*kruskal-wallis*, P<0.05). The percent of respondents who disagreed with the statements that scheme participation brought about positive change was significantly lower for farms currently in Glastir relative to the farms exiting scheme, and was correspondingly higher for respondents who agreed with the statements (*kruskal-wallis*, P<0.05). **Figures 12.6** and **12.7** shows the cumulative distribution of Likert scores for each scheme history.

For all perceived outcomes, regardless of scheme participation history, the distributions of Likert scores were strongly positively correlated with the scores for '*change in management of my farm*' (*ordinal regression*, P<0.01). Farm managers that agreed that change in management had occurred were also more likely to report improvement in each of the outcomes (**Figure 12.8 and 12.9**). The polychoric correlation coefficients between the management and outcome scores were in the range 0.36 to 0.55 and were generally lowest for the more difficult to assess impact on diffuse water pollution and climate change (**Table 12.6**).

Likert scores for the '*enhanced the plants and wildlife on my farm*' and '*improved the appearance of my farm*' outcomes were significantly higher on farms currently participating in the higher level Glastir Advanced scheme or having exited the preceding Tir Gofal scheme (*ordinal regression*, P<0.01). Other factors including farm type and size had no statistically significant effect on the outcome scores (*ordinal regression*, P>0.10).

Expanded Interest

Survey respondents self-assessed the '*expanded interest in the public benefits of farming*' resulting from scheme participation also using a Likert scale. Overall, between 35 and 47% of farms disagreed or strongly disagreed that there had been any change, and between 14 and 29% agreed or strongly agreed that there had been change (**Table 12.9**). There was little difference due to scheme participation history.

The polychoric correlation coefficients between the score for expanded interest in public benefits and the perceived outcomes were in the range 0.37 to 0.56 (**Table 12.10**). There was a strong positive correlation between the score and the individual perceived outcome scores regardless of scheme participation history (**Figure 12.10** and **12.11**). Although all of the outcome scores were individually correlated with the score for expanded interest in public benefits, multiple regression analyses consistently excluded the outcome scores for '*reduced my farms contribution to the pollution of rivers and lakes*' and '*reduced my farms contribution to climate change*'.

Based on self-assessment there is evidence that participation in the Advanced level of Glastir scheme brought about a greater degree of farm management change compared to the Entry level. This degree of change was substantially less than reported under the preceding Tir Cynnal or Tir Gofal schemes in an earlier survey. However, the lasting *effect of these schemes on farm management was more comparable. Overall, the effect of scheme participation is small compared to the considerable variation in the degree of management change reported across all farm types and levels of scheme participation. The degree of management change was strongly correlated with perceived improvements in farm business health and planning, reduction of diffuse pollution and enhancement of farm plants, wildlife and appearance.*

Table 12.2 Percent of farms in this surveys' sample pool participating in each of the Welsh agri-environment schemes, stratified by farm type and farm size defined by standard labour requirement.

Glastir Entry	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**		**Tir Cynnal**	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**
SLR1b	13	16	8		SLR1b	17	20	19
SLR2	15	26	11		SLR2	21	22	25
SLR3	21	31	13		SLR3	22	23	25
SLR4	25	38	20		SLR4	22	24	21
SLR5	23	35	22		SLR5	20	13	23
Grand Total	**16**	**29**	**16**		**Grand Total**	**20**	**21**	**23**
Glastir Advanced	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**		**Tir Gofal**	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**
SLR1b	5	7	0		SLR1b	15	17	8
SLR2	6	11	3		SLR2	18	24	10
SLR3	11	17	4		SLR3	26	33	14
SLR4	14	20	5		SLR4	34	39	18
SLR5	20	27	8		SLR5	35	46	25
Grand Total	**8**	**15**	**5**		**Grand Total**	**20**	**30**	**16**

Table 12.3 Percent of farms in this surveys' sample pool participating in each of the Welsh agri-environment schemes, stratified by farm type and farm size defined by standard gross margin.

Glastir Entry	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**		**Tir Cynnal**	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**
SGM1	13	12			SGM1	18	20	
SGM2	15	27	13		SGM2	19	22	23
SGM3	21	38	13		SGM3	21	22	24
SGM4	21	35	18		SGM4	16	8	24
SGM5		39	21		SGM5	50	13	22
Grand Total	16	29	16		Grand Total	20	21	23
Glastir Advanced	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**		**Tir Gofal**	**CS-DA+CS-LOW**	**CS-SDA**	**DAIRY**
SGM1	4	8			SGM1	13	16	
SGM2	7	13	1		SGM2	19	27	7
SGM3	13	21	4		SGM3	31	40	12
SGM4	14	25	5		SGM4	25	46	18
SGM5	25	26	7		SGM5	50	65	23
Grand Total	8	15	5		Grand Total	20	30	16

Table 12.4 Farm segmentation for all farms in Wales (Woolf *et al*., 2016) and for farms with woodland that have or have not taken up a grant for woodland management (Cao and Elliott, 2015).

Farm Segment	**Characterisation**	**Cao and Elliott (2015)**		**Woolf *et al*. (2016)**
		Non Grant (n 592)	**Grant (n 413)**	**All Farms (n 1814)**
C	Open Environmentalist	23	27	35
Y	Moderately Open	20	26	18
M	Traditional Environmentalist	16	14	23
R	Traditional Productivist	21	16	13
U	Open Productivist	20	17	11

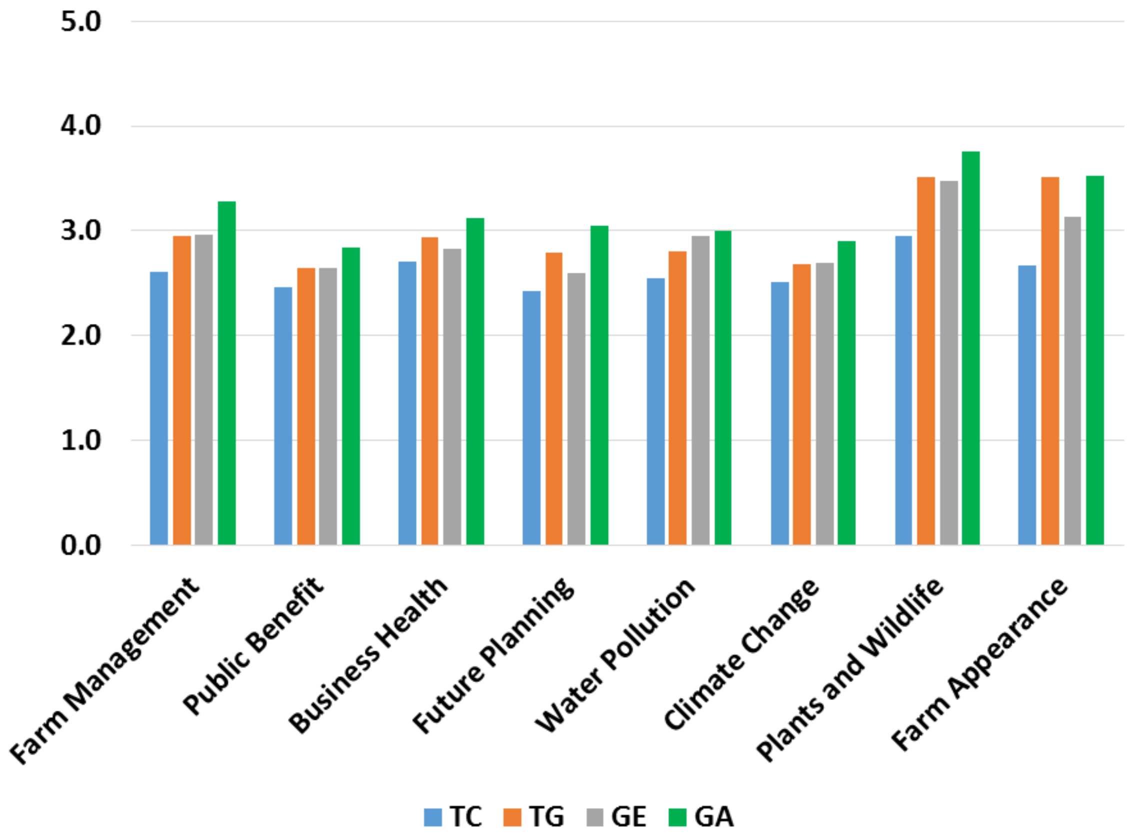


Figure 12.3 Average Likert scores for self-assessed change in farm management, expanded interest in the public benefits of farming, and perceived scheme outcomes, stratified by farms currently participating in the Glastir Entry (GE) or Advanced (GA) scheme, and farms that had exited the previous Tir Cynnal (TC) or Tir Gofal (TG) schemes.

Table 12.5 Percent distribution of Likert scores for a (lasting) '*change in my management of the farm*' on farms having exited the preceding Tir Cynnal or Tir Gofal scheme, or currently participating in the Glastir Scheme.

	Tir Cynnal or Tir Gofal		Glastir Entry or Advanced Scheme	
Level	**TG (n 63)**	**TC (n 75)**	**GA (n 155)**	**GE (n 125)**
Strongly Disagree	24	23	8	10
Disagree	6	17	12	20
Neither	35	41	39	42
Agree	21	13	23	17
Strongly Agree	14	5	17	10

Table 12.6 Polychoric correlation coefficient between Likert scores for self-assessed (lasting) '*change in my management of the farm*' and perceived outcomes of scheme participation, on farms having exited the preceding Tir Cynnal or Tir Gofal scheme, or currently participating in the Glastir Scheme.

Outcome	Glastir Entry or Advanced Scheme	Tir Cynnal or Tir Gofal
Improved Business Health	0.45	0.53
Helped Plan for Future	0.47	0.55
Reduced Water Pollution	0.34	0.46
Reduced Climate Change	0.35	0.40
Enhanced Plants and Wildlife	0.41	0.46
Improved Farm Appearance	0.40	0.49

Table 12.7 Percent distribution of Likert scores for (lasting) perceived outcomes, on farms having exited the preceding Tir Cynnal or Tir Gofal schemes.

Tir Gofal						
Level	**Business Health (n 63)**	**Future Planning (n 63)**	**Water Pollution (n 63)**	**Climate Change (n 63)**	**Plants and Wildlife (n 63)**	**Farm Appearance (n 63)**
Strongly Disagree	17	22	21	27	10	8
Disagree	19	22	19	16	13	17
Neither	29	21	30	29	19	17
Agree	22	24	19	19	35	30
Strongly Agree	13	11	11	10	24	27
Tir Cynnal						
Level	**Business Health (n 75)**	**Future Planning (n 75)**	**Water Pollution (n 75)**	**Climate Change (n 75)**	**Plants and Wildlife (n 75)**	**Farm Appearance (n 75)**
Strongly Disagree	21	28	23	20	15	20
Disagree	21	25	24	24	15	16
Neither	29	27	31	43	40	44
Agree	21	16	21	12	23	17
Strongly Agree	7	4	1	1	8	3

Table 12.8 Percent distribution of Likert scores for perceived outcomes, on farms currently in the Glastir Entry and Advanced schemes.

Glastir Advanced						
Level	**Business Health (n 155)**	**Future Planning (n 155)**	**Water Pollution (n 155)**	**Climate Change (n 155)**	**Plants and Wildlife (n 155)**	**Farm Appearance (n 155)**
Strongly Disagree	11	12	16	13	6	12
Disagree	19	19	15	24	11	12
Neither	29	33	34	32	13	17
Agree	28	25	21	24	40	33
Strongly Agree	12	12	14	8	30	27
Glastir Entry						
Level	**Business Health (n 125)**	**Future Planning (n 125)**	**Water Pollution (n 125)**	**Climate Change (n 125)**	**Plants and Wildlife (n 125)**	**Farm Appearance (n 125)**
Strongly Disagree	17	19	17	17	6	14
Disagree	18	26	22	26	10	15
Neither	38	34	22	34	30	26
Agree	18	18	27	15	37	30
Strongly Agree	8	3	12	7	17	14

Table 12.9 Percent distribution of Likert scores for a (lasting) '*expanded interest in the public benefits of farming*', on farms having exited the preceding Tir Cynnal or Tir Gofal scheme, or currently participating in the Glastir Scheme.

	Tir Cynnal or Tir Gofal		**Glastir Entry or Advanced Scheme**	
Level	**TG (n 63)**	**TC (n 75)**	**GA (n 155)**	**GE (n 125)**
Strongly Disagree	21	23	18	21
Disagree	24	24	17	22
Neither	35	40	35	33
Agree	11	11	21	20
Strongly Agree	10	3	8	4

Table 12.10 Polychoric correlation coefficient between Likert scores for perceived outcomes of scheme participation and self-assessed (lasting) '*expanded interest in the public benefits of farming*', on farms having exited the preceding Tir Cynnal or Tir Gofal scheme, or currently participating in the Glastir Scheme.

Outcome	Glastir Entry or Advanced Scheme	Tir Cynnal or Tir Gofal
Improved Business Health	0.51	0.48
Helped Plan for Future	0.56	0.50
Reduced Water Pollution	0.37	0.37
Reduced Climate Change	0.42	0.41
Enhanced Plants and Wildlife	0.47	0.49
Improved Farm Appearance	0.52	0.41

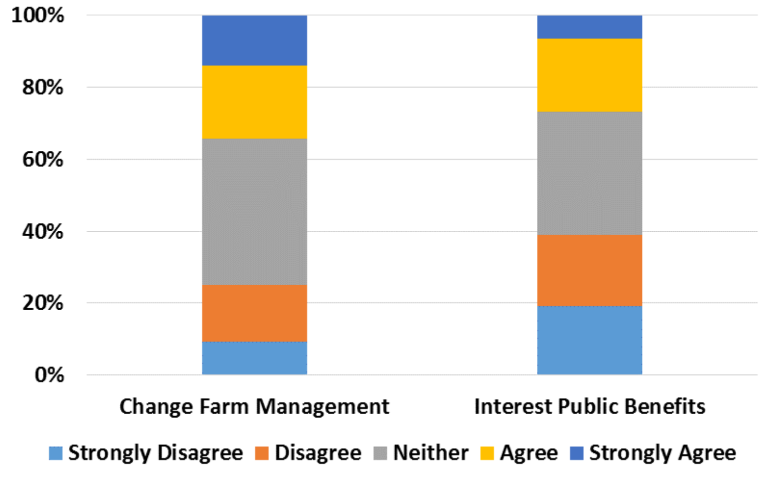


Figure 12.4 Cumulative distribution of Likert scores for self-assessed effect of scheme participation on change in farm management and expanded interest in public benefits of farming, for farms participating in the Glastir scheme.

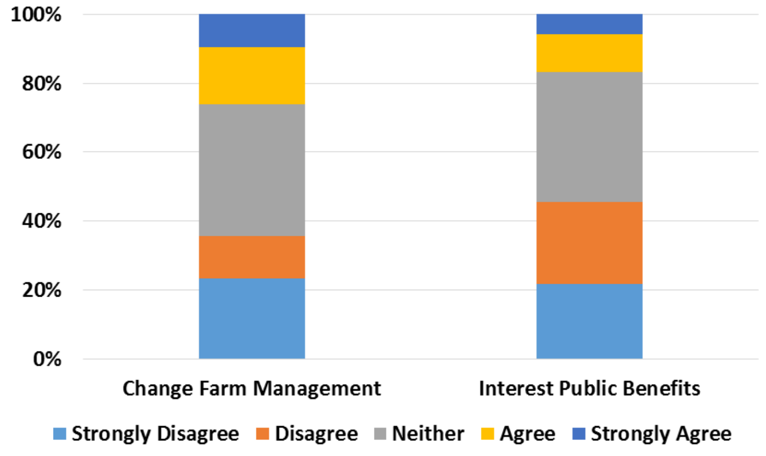


Figure 12.5 Cumulative distribution of Likert scores for perceived (lasting) effect of scheme participation on change in farm management and expanded interest in public benefits of farming, for farms participating in the Tir Cynnal or Tir Gofal schemes.

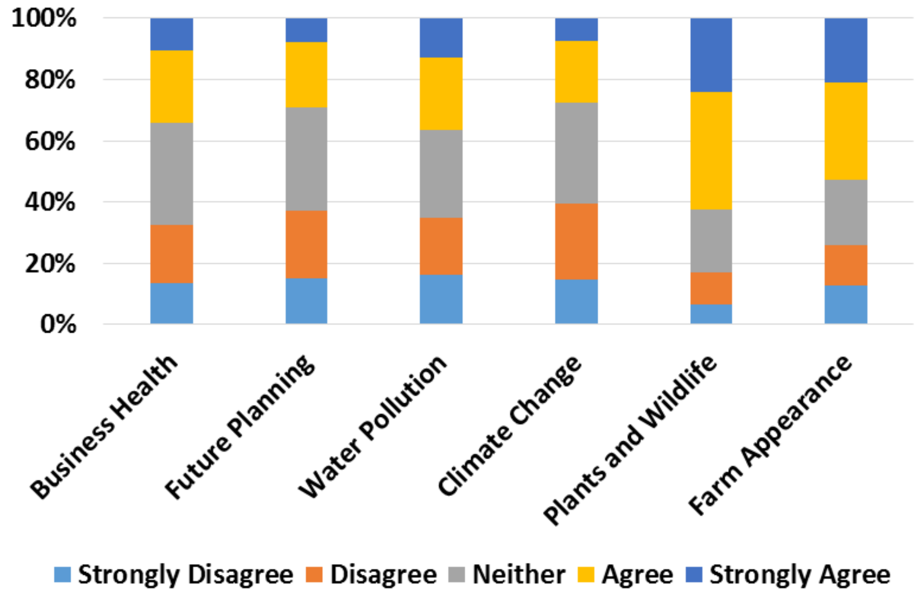


Figure 12.6 Cumulative distribution of Likert scores for perceived (lasting) outcomes of scheme participation on farms participating in the Glastir scheme.

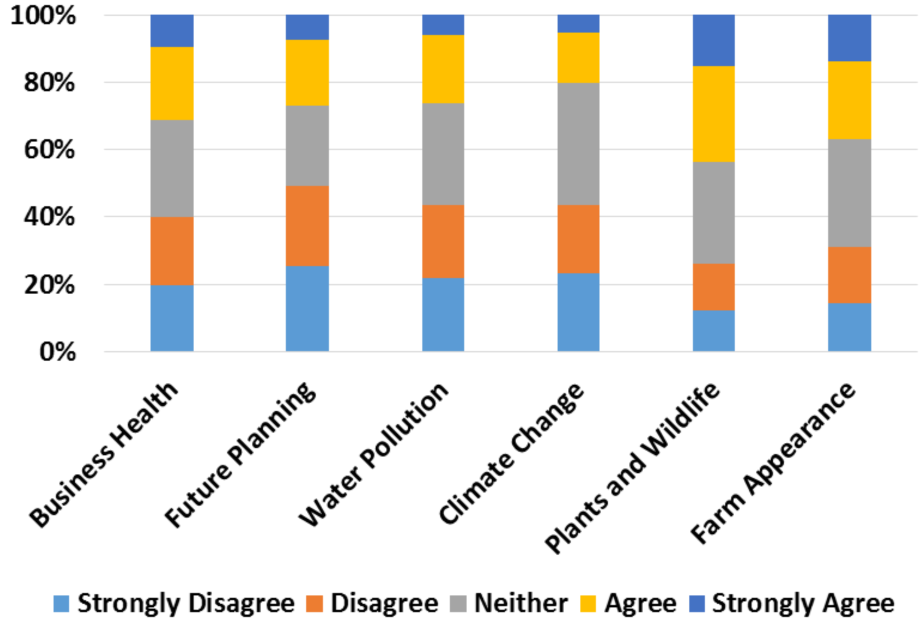


Figure 12.7 Cumulative distribution of Likert scores for perceived (lasting) outcomes of scheme participation on farms exiting the Tir Cynnal or Tir Gofal schemes.

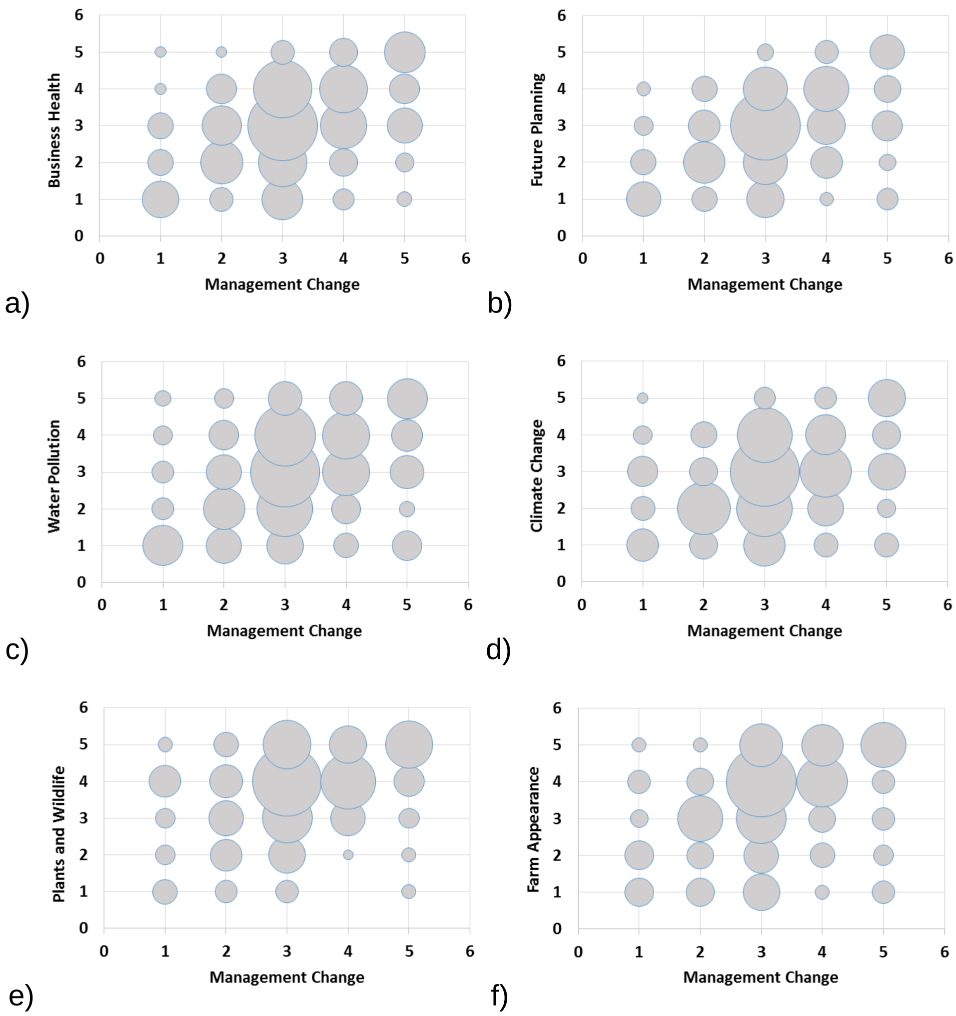


Figure 12.8 Correlation between Likert scores for farms participating in the Glastir scheme, for self-assessed ‘*change in my management of the farm*’ attributed to scheme participation and perceived scheme outcomes including a) ‘*improved business health*’; b) ‘*helped plan for the future*’; c) ‘*reduced 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.

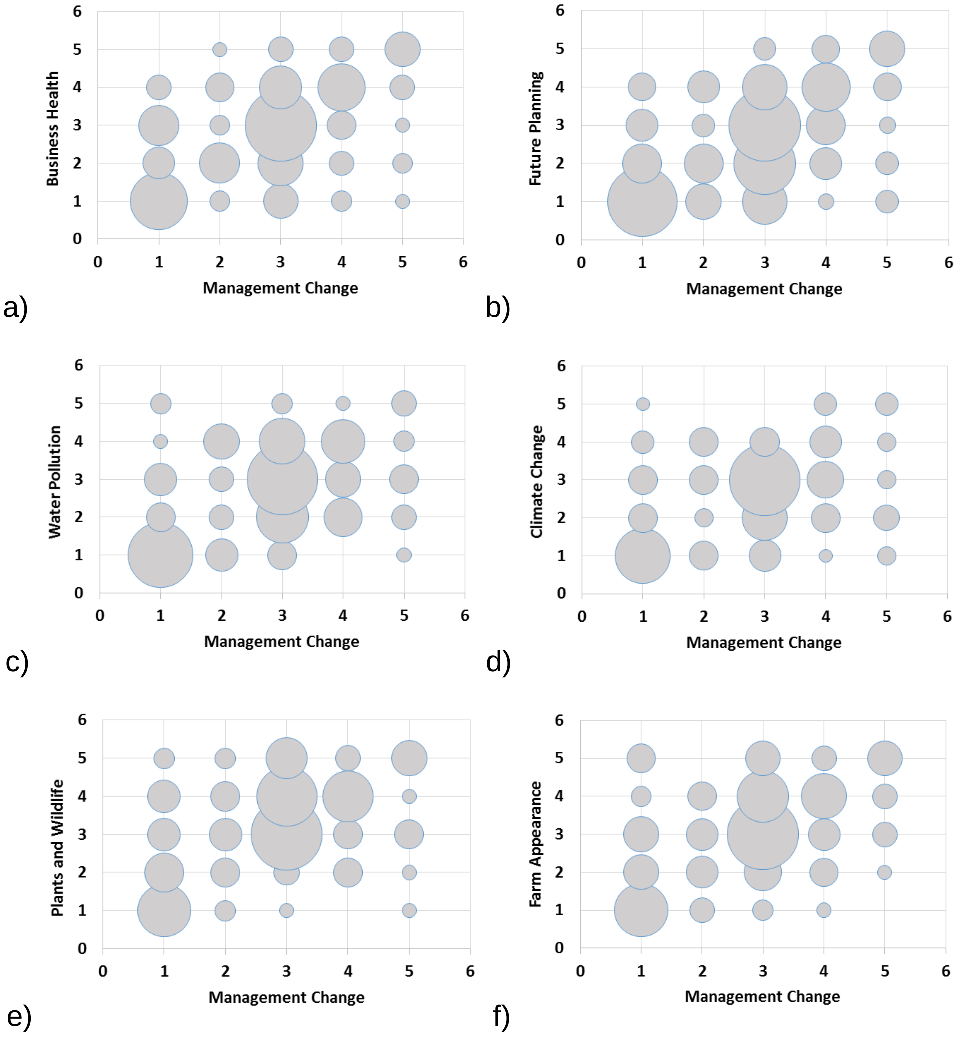


Figure 12.9 Correlation between Likert scores for farms exiting the Tir Cynnal or Tir Gofal scheme, for self-assessed lasting '*change management of my farm*' attributed to scheme participation and perceived lasting scheme outcomes including a) '*improved business health*'; b) '*helped plan for the future*'; 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.

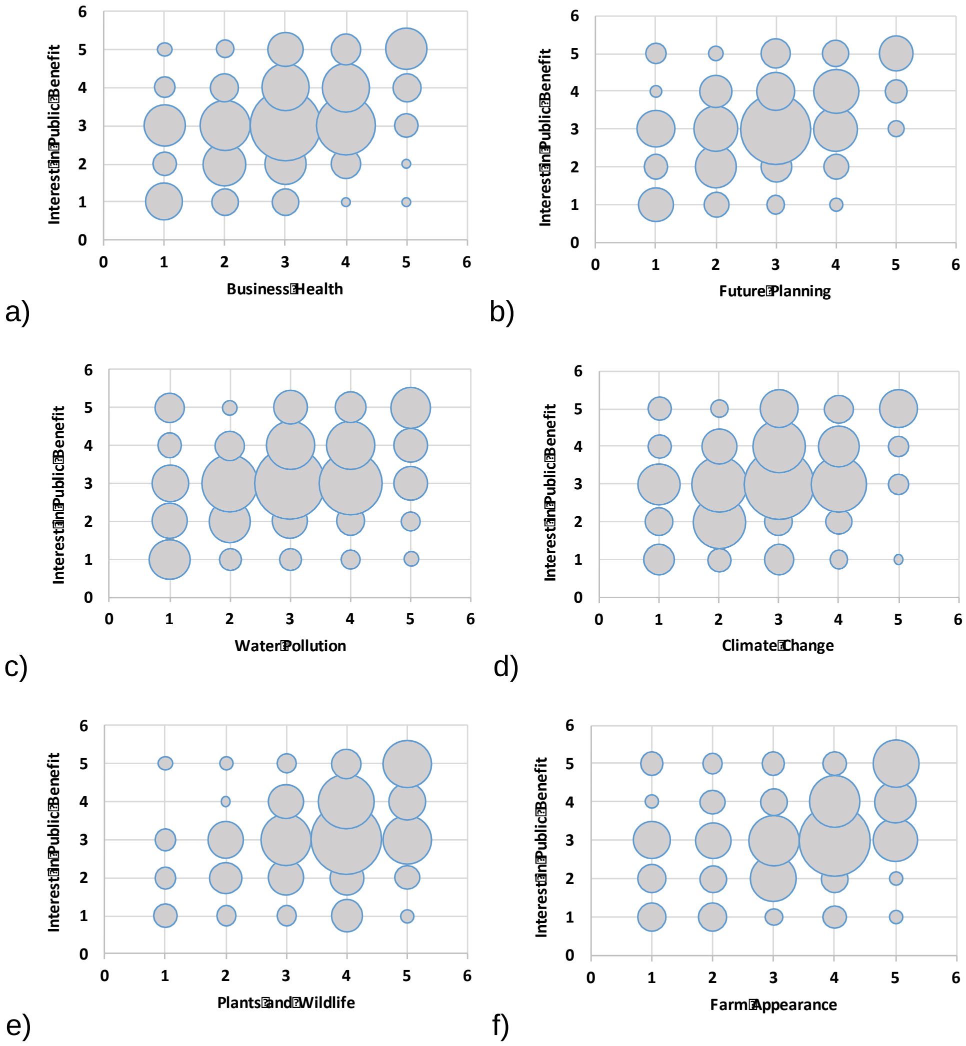


Figure 12.10 Correlation between Likert scores for farms participating in the Glastir scheme, for self-assessed '*expanded interest in the public benefits of farming*' attributed to scheme participation and perceived scheme outcomes including a) '*improved business health*'; b) '*helped plan for the 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.

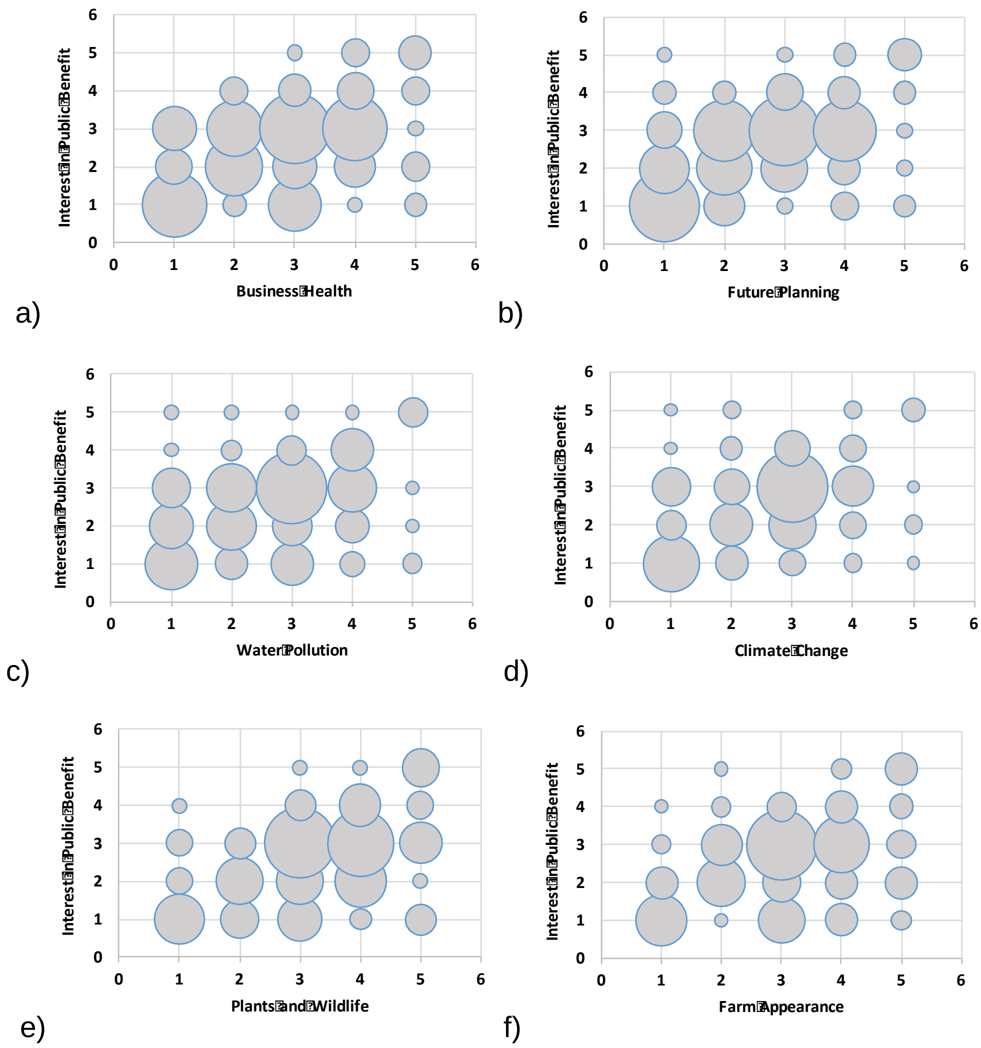


Figure 12.11 Correlation between Likert scores for farms exiting the Tir Cynnal or Tir Gofal schemes, for self-assessed (lasting) '*expanded interest in the public benefits of farming*' attributed to scheme participation and scheme perceived outcomes including a) '*improved business health*'; b) '*helped 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.

13. Non-Participation

Hypothesis: *reasons for not participating in the Glastir scheme relate to perceived complexity and payment rates.*

Respondents that were not currently participating in the Glastir scheme were asked to cite the reasons that had prevented or delayed participation. Reasons were drawn from a prepared list, with the option to provide additional reasoning (**Tables 13.1** and **13.2**).

For farms that had not participated in any scheme, there were no differences between farm types in the reasons cited for not having participated (*fisher exact test*, P>0.10). Perceived complexity (42%) and a lack of fit with the farming system (53%) were cited most frequently. A general lack of interest was cited by 35% of respondents. On a few occasions this could be directly related to additional reasoning volunteered by the respondents. For example, the intention to plough and drain grassland were perceived as incompatible with the Glastir scheme by one respondent, and another believed they had achieved what was needed under the preceding Tir Gofal scheme. Generally, respondents volunteered additional concerns regarding paperwork and restrictions on management (7%) and a minority of respondents cited other factors such as retirement (3%), ill health (1%) or insufficient points for entry (1%).

Table 13.1 Percent of farms that have never participated in scheme, citing reasons for not having participated in any of the Tir Cynnal, Tir Gofal or Glastir schemes, stratified by farm type.

Reason	DAIRY (*n* 41)	CS-SDA and CS-LOW+CS-DA (*n* 109)
I applied but was not accepted	7 (0 to 15)	6 (2 to 10)
It would not fit with my farming system	59 (41 to 73)	51 (42 to 61)
I did not want to be tied to a scheme for 5 years	27 (15 to 41)	35 (26 to 44)
The scheme was too complicated	46 (32 to 61)	41 (32 to 50)
The payment rate was insufficient	34 (20 to 49)	26 (17 to 34)
I was not interested	34 (20 to 49)	36 (28 to 45)

Table 13.2 Percent of farms that had previously participated in the Tir Cynnal of Tir Gofal scheme, citing reasons for preventing or delaying participation in the Glastir scheme, stratified by farm type.

Reason	DAIRY (*n* 35)	CS-SDA and CS-LOW+CS-DA (*n* 103)
I applied but was not accepted	11 (3 to 23)	9 (4 to 15)
It would not fit with my farming system	51 (34 to 66)	30 (21 to 40)
I did not want to be tied to a scheme for 5 years	26 (11 to 40)	21 (14 to 29)
The scheme was too complicated	43 (26 to 60)	37 (28 to 47)
The payment rate was insufficient	57 (40 to 74)	31 (22 to 40)
I was not interested	23 (9 to 37)	25 (17 to 34)

For farms that had previously participated in the Tir Cynnal or Tir Gofal scheme, the percent of dairy farms citing that the Glastir scheme would "*not fit with my farming system*" or that "*the payment rates was insufficient*" was significantly higher than for the cattle and sheep farm types (*fisher exact test*, P<0.05). Dairy farm types that had previously participated in Tir Cynnal or Tir Gofal were more likely to cite insufficient payment rates than farms that had never participated, whilst cattle and sheep farm types were less likely to cite a lack of fit with farming system (*fisher exact test*, P<0.05). The responses suggest that concerns regarding payment rate and lack of fit have been validated by previous experience of scheme participation on dairy farms.

> *"It has improved the view. We now have proper fences, good hedges and stock proof fields. You can put a cow in a field and it will be there in the morning. It makes management much easier."*
>
> *"It has improved it - I like to see the streams fenced off. We wouldn't have done it otherwise - it was the encouragement from Glastir."*
>
> *"It's improved the shelter and hedges and the appearance of the farm."*
>
> *"Because we fenced off water courses, so that stops the cattle wandering through and making the brooks wider. Making a wildlife corridor has improved the look of the farm."*

At the conclusion of the survey, respondents were also invited to comment on how participation in Glastir had improved the farm or hindered farm management, and all respondents including those not in scheme were invited to nominate a priority improvement to the Glastir scheme. The responses were as varied as are the farms, but there were some themes that reflected the concerns of those who had not entered scheme.

Of those presently in some element of the Glastir scheme (*n* 303), 59% cited some improvement to the farm and 41% either explicitly stated that the scheme had not resulted in an improvement (*n* 45) or did not provide a response (*n* 78) to the question.

The most frequently cited farm improvements were to field boundaries, including secure fencing, the rebuilding of stone walls and restoration of hedgerows (*n* 54) and the receipt of grant payments (*n* 32) enabling this work or contributing to the farm business.

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.

"More record keeping. It hasn't helped me - it's just caused more work."

"Some of the prescriptions of how you can do things are a little awkward to fit in with the weather. Certain things are just based on date rather than the seasonal factors.

"When you have to take your sheep off and you are not allowed to bring them back on, and the paperwork. I have to rent other farms for my sheep and have to rent all year around because they're not allowed on a hill."

"During the winter if any work needs doing by a certain date but you are calving or lambing or it is too wet, it's hard for a family farm."

Of those presently in some element of the Glastir scheme (*n* 303), 40% cited some hindrance to farm management and 60% either explicitly stated that the scheme had not resulted in any hindrance (*n* 43) or did not provide a response (*n* 139).

The most frequently cited hindrance after paperwork and bureaucracy (*n* 31) related to restrictions on timing of stock and field management (*n* 16), especially in regard to prevailing weather, and on maximum stocking rates on hill pasture (*n* 15).

"Make it easier to understand. Stop putting everything online. Make things simpler and easier because the paperwork isn't a priority."

"Accept that there are no set rules in farming - be a little more adaptable and flexible"

"Extend some dates when the weather is prohibiting you from doing things."

"Ease up a little bit. They should put capital works over three or four years, not two. Farmers have to get contractors which they can't always do so they are unable to finish on time."

Of the farms not presently in the Glastir scheme, 68% did not make a suggestion for an improvement in the scheme, compared to 28% of farms presently in scheme.

Out of 314 respondents giving some suggestion for a priority improvement, the most frequent request was for simplification of the scheme and associated paperwork (*n* 69), followed by recognition of the need for flexibility in the timing of land management and capital improvements (*n* 49).

"It would be nice if they would tell us if they're going to continue with the Glastir scheme."

Higher scheme payments, and more specifically more timely payments of grants for capital items (*n* 40), were followed by a need for improved information and frequent and direct communication with scheme officers (*n* 34).

"Easier access to get in on the scheme because it's pretty tough at the moment."

"The Glastir scheme I would say is an intrusive scheme which is not always tailored to a particular farm's situation."

Security of funding and the life-time of the scheme was also a concern in the context of *Brexit* and the imminent termination of 5 year agreements (*n* 21).

Those outside the scheme also requested that it was easier to access (*n* 26) and tailored for individual farms situations.

"*They want the whole farm. It would have been good to cut corners on the farm for livestock and the wildlife*"

"Making it a part farm scheme for the areas which have habitat."

"It's a marvellous scheme, but as I have got a son of 15 interested in farming it would mean a reduction in stock and I don't want to do that. It is a good scheme for someone who hasn't got any sons or daughters interested in farming."

"Because it doesn't allow us to increase our stock or farm better - it's all about non-farming practises. You know, it's holding us back from

Whilst there was an appreciation of the objectives of Glastir, especially relating to change for the benefit of wildlife and plants, there were a few responses that reflected the self-identification of farmers as producers and the desire to meet both agricultural and environmental objectives.

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Appendix A – Generic Analysis Scripts

Generic Script No. 1 Mean and Confidence Interval

```
# Generic script for calculation of mean and empirical 95-percent
# confidence interval of the mean by boot-strap re-sampling of an
# [ATTRIBUTE], stratified by an [AGGREGATE] level.

library(MASS)
library(mfx)
library(pscl)
library(plyr)
library(ordinal)
library(survey)

# read input file;
inputfile <- "F://[FILEPATH].CSV"
mydata <- read.csv(inputfile,header=T)

# apply data row filtering rules as required;
mydata <- mydata[mydata$IS_USE == 1,]

# visual health check on data;
head(mydata)

# extract aggregate level and attribute to be summarised into new table;
mycomb <- as.data.frame(cbind(Group = mydata$[AGGREGATE], Obs =
mydata$[ATTRIBUTE]))

# calculate average attribute value for each aggregate level;
myddply <- ddply(mycomb, .(Group), summarise,
countObs=length(Obs),meanObs=mean(Obs))

# random re-sampling of the attribute, with replacement, within each
aggregate level;
myrep <- myddply[,1:2]
```

```
for(idx in 1:10000){

  mysample <- ddply(mycomb, .(Group), function(x)
x[sample(replace=TRUE,nrow(x),nrow(x)),])

  myrandom <- ddply(mysample, .(Group) , summarise, meanObs=mean(Obs))

  myrep[,idx] <- myrandom$meanObs
}

# extraction of 2.5 and 97.5 percentile estimates of attribute mean;
myddply[,ncol(myddply)+1] <- 0
names(myddply)[ncol(myddply)] <- "LowObs"
myddply[,ncol(myddply)+1] <-0
names(myddply)[ncol(myddply)] <- "UppObs"


for(idx in 1:nrow(myddply))
{
  myddply[idx,ncol(myddply)-1] <- quantile(myrep[idx,1:10000],0.025)

  myddply[idx,ncol(myddply)] <- quantile(myrep[idx,1:10000],0.975)

}

# display calculated attribute mean and confidence interval for each
aggregate level;
myddply
```

Generic Script No. 2 Binomial Generalised linear Model and Marginal Effect

```
# Generic script for fitting of Generalised linear Model (binomial)
# to explain proportion of respondents carrying out an [ACTION]
# as a function of nested farm type ([IS_CS]/[IS_SDA]) and nested
# scheme participation ([IS_TCTG]/[IS_TG] and [IS_GEGA]/[IS_GA]).
# Best model is determined by forward and backward search using
# Akaike Information Criterion. Marginal effects are calculated
# for the sample population.

library(MASS)
library(mfx)
library(pscl)
library(plyr)
library(ordinal)
library(survey)


# read input file;
inputfile <- "F://[FILEPATH].CSV"
mydata <- read.csv(inputfile,header=T)


# apply data row filtering rules as required;
mydata <- mydata[mydata$IS_USE == 1,]

myglm <- glm(data=mydata, family="binomial", weights=NULL, [ACTION] ~
IS_CS/IS_SDA + IS_TC + IS_TG + IS_GEGA/IS_GA)

# Search for best predictors using AIC;
mystep <- step(myglm, k=2)

# Trim predictors to minimum required confidence level;
myglm <- glm(data=mydata, family="binomial", mystep$formula)
kk <- qchisq(0.05,1,lower.tail=FALSE)
```

```
mystep <- step(myglm, k=kk)


# Display parameters and coefficients of best model;

summary(mystep)


# Display pseudo r2 Macfadden statistic for model fit;

pR2(mystep)


# calculate and display marginal effects for the sampe dataset;

mymfx <- logitmfx(formula(mystep), data=mydata, atmean = TRUE, robust =
FALSE, clustervar1 = NULL,clustervar2 = NULL, start = NULL, control =
list())


mymfx
```

Generic Script No. 3 Poisson Generalised linear Model and Marginal Effect

```
# Generic script for fitting of Generalised linear Model (poisson)
# to explain the count of [ACTION] carried out by respondents
# as a function of nested farm type ([IS_CS]/[IS_SDA]) and nested
# scheme participation ([IS_TCTG]/[IS_TG] and [IS_GEGA]/[IS_GA]).
# Best model is determined by forward and backward search using
# Akaike Information Criterion. Marginal effects are calculated
# for the sample population.

library(MASS)
library(mfx)
library(pscl)
library(plyr)
library(ordinal)
library(survey)



# read input file;
inputfile <- "F://[FILEPATH].CSV"
mydata <- read.csv(inputfile,header=T)



# apply data row filtering rules as required;
mydata <- mydata[mydata$IS_USE == 1,]


myglm <- glm(data=mydata, family="poisson", weights=NULL, [ACTION] ~
IS_CS/IS_SDA + IS_TC + IS_TG + IS_GEGA/IS_GA)


# Search for best predictors using AIC;
mystep <- step(myglm, k=2)


# Trim predictors to minimum required confidence level;
myglm <- glm(data=mydata, family="poisson", mystep$formula)
kk <- qchisq(0.05,1,lower.tail=FALSE)
```

```
mystep <- step(myglm, k=kk)

# Display parameters and coefficients of best model;
summary(mystep)

# Display pseudo r2 Macfadden statistic for model fit;
pR2(mystep)

# calculate and display marginal effects for the sampe dataset;
mymfx <- poissonmfx(formula(mystep), data=mydata, atmean = TRUE, robust =
FALSE, clustervar1 = NULL,clustervar2 = NULL, start = NULL, control =
list())

mymfx
```

Generic Script No. 4 Ordinal Regression Model

```
# Generic script for fitting of Ordinal Regression Model to Likert
# responses to test whether the distribution of [SCORES] given by
# respondents differs as a function of nested farm type ([IS_CS]/
# [IS_SDA]) or advanced level of scheme participation ([IS_TG] or
# [IS_GA]) separately for groups of farms that had either exited
# the preceding TC or TG schemes (and were not participating in
# Glastir) or had entered the GE or GA schemes.
# Best model is determined by forward and backward search using
# Akaike Information Criterion.

library(MASS)
library(mfx)
library(pscl)
library(plyr)
library(ordinal)
library(survey)


# read input file;
inputfile <- "F://[FILEPATH].CSV"
mydata <- read.csv(inputfile,header=T)


# apply data row filtering rules as required;
mydata <- mydata[mydata$IS_USE == 1,]

# redesignate response as a factor;
mydata$[SCORES] <- as.factor(mydata$[SCORES])


# if testing effect of exit from TC or TG then:
myord <- clm([SCORES] ~ IS_CS/IS_SDA + IS_TG, weights = NULL, data =
mydata)
```

```
# else if testing effect of entry to GE or GA then:

myord <- clm([SCORES] ~ IS_CS/IS_SDA + IS_GA, weights = NULL, data =
mydata)


# Search for best predictors using AIC;

mystep <- step(myord, k=2)


# Trim predictors to minimum required confidence level;

myord <- clm(data = mydata,formula=mystep$formula)

kk <- qchisq(0.05,1,lower.tail=FALSE)

mystep <- step(myord, k=kk)


# Display parameters and coefficients of best model;

summary(mystep)
```

Generic Script No. 5 Global and Multiple Pair-Wise Comparisons

```
# Generic script for calculating global test of at least
# one significant difference between pair-wise values of
# [ACTION] counts (kruskal-wallis) or proportions (fisher
# exact) aggregated by [GROUP], and followed by post-hoc
# multiple pair-wise comparisons of [ACTION] counts (dunn)
# or proportions (fisher exact) with the required Benjamini
# Hochberg adjustment to significance probabilities.

library(plyr)
library(binomTools)
library(pbkrtest)
library(RVAideMemoire)
library(dunn.test)

# read input file;
inputfile <- "F://[FILEPATH].CSV"
mydata <- read.csv(inputfile,header=T)



# apply data row filtering rules as required;
mydata <- mydata[mydata$IS_USE == 1,]

# if data are proportions then:

# build binomial contingency table;
myglm <- glm(paste([ACTION], "[GROUP]", sep =" ~ "), data = mydata, family
= "binomial")

mygroup <- group(myglm,eval=TRUE)
mymatrix <- mygroup$newData

# apply fisher exact tests for proportion data;
fisher.test(mymatrix$YY)
```

```
fisher.multcomp(mymatrix$YY, p.method="BH")

# else if data are counts then:

# apply kruskal and dunn test for count data;
kruskal.test(mydata$[ACTION], mydata$[GROUP])

dunn.test(mydata$[ACTION], mydata$[GROUP], method="bh")
```