Catchment Sensitive Farming

Evaluation Report – Water Quality Phases 1 to 4 (2006-2018)

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Environment Agency
June 2019

A clear solution for farmers

CATCHMENT SENSITIVE FARMING

This report should be cited as: Environment Agency (2019) *Catchment Sensitive Farming Evaluation Report – Water Quality, Phases 1 to 4 (2006-2018).* Natural England publication, June 2019.

Executive summary

Launched in December 2005, the Catchment Sensitive Farming (CSF) partnership is an advice-led initiative enabling action by farmers to reduce agricultural pollution. CSF's primary objective is to encourage voluntary action to help achieve Water Framework Directive, National Emission Ceilings Directive and SSSI targets. Delivered in partnership by Natural England and the Environment Agency, CSF contributes to Government targets for 'Clean and plentiful water' and 'Clean air' set out in the 25 Year Environment Plan.

Monitoring and evaluation are core elements of CSF. Evaluation informs decisions on the future of CSF, including ongoing improvement (of design and implementation) and reinvestment, as well as informing wider policy development.

After twelve years, evaluation demonstrates that CSF has made significant progress in delivering its water quality objectives[1]. Success has been underpinned by effective farmer engagement and advice delivery achieved through a combination of CSF Officers, commissioned contractors, and partnerships with other organisations.

Targeting areas where action is most needed, CSF has delivered extensive farmer engagement and advice delivery. The 19,776 farms engaged represent 34 per cent of the total farmed area of England. Using an effective mix of one-to-one and group engagements, significant importance has been placed on building relationships across the farming community. Overall, farmers are very positive about their experiences of CSF and indicate CSF Officers provide them with relevant and trusted advice.

76,700 individual pollution mitigation measures[2] have been implemented on farms following (one-to-one) CSF advice. The majority are judged to be 'mostly effective'. Cost is the most significant barrier to implementation of measures, but capital grants (initially available through CSF and now through Countryside Stewardship) are a strong enabler and driver of action. CSF advice is making a positive contribution to delivery of Countryside Stewardship objectives for water.

Nutrient, sediment, faecal indicator organism and pesticide pressures have been reduced within those areas where pressures from agriculture are greatest. These reductions contribute towards achieving sector-weighted water quality targets. CSF is, however, part of a wider policy mix and, in the majority of cases, will not achieve these targets on its own.

Water quality improvements are evident in monitoring data, after accounting for a range of confounding factors (for example, weather variation and changes in cropping patterns and livestock densities).

CSF requires time in a catchment to achieve widespread farmer engagement, establish effective farmer relationships, provide farm advice and grant support, and achieve significant uptake of mitigation measures on farms. Our evidence indicates a lag of around three years before mitigation measures produce a detectable water quality improvement.

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[1] Progress against air quality objectives will be considered in a separate report

[2] Estimate based on 59.6 per cent implementation of 128,691 advised measures

Both extended timescales (to allow for further CSF delivery, lags in the system and building more comprehensive datasets) and refined evaluation methods will be needed to determine the ecological and groundwater benefits from CSF.

There are indications that CSF is reducing the occurrence of water pollution incidents, relating to agriculture, where advice delivery has been most focused, but incidents are increasing in areas where there are agricultural pressures and less focused CSF delivery.

The benefits of CSF go well-beyond water quality. Natural capital benefits particularly associated with CSF also include biodiversity, provision of animal products and materials, erosion control, reduced flood risk, natural pest control, and beneficial insect pollination.

Looking forward, evaluation remains fundamental to the success of CSF. Further work is planned to support continuous improvement of CSF delivery and ensure the evaluation of benefits is increasingly robust and comprehensive. As the policy framework evolves, we will look to adapt the approach developed for CSF in order to provide a more integrated assessment of water policies relating to agriculture.

Contents

Headline statistics

19,776 farm holdings have received CSF advice

34% of total farmed area in England managed by CSF-engaged farmers

53% of farm holdings engaged on three or more occasions

128,691 farm-specific mitigation measures advised

59.6% of advised farm-specific measures implemented

87% of implemented measures assessed to be 'mostly effective'

£84M of grant-funded improvements match-funded by farmers (2007-14)

4-12% reduction in agricultural pollutant losses (average across Phase 1 Target Areas)

4-8 times higher reductions in agricultural pollutant losses from within agri-environment scheme farms also implementing CSF measures

1-6% modelled water quality improvement (averaged across water bodies associated with Phase 1 CSF Target Areas or, for FIOs, all areas targeted consistently since Phase 1)

34% reduction in monitored pesticide concentrations exceeding 0.1µg/l (across monitored CSF catchments)

5-22% reduction in monitored nutrient, sediment and FIO concentrations (averages of four responsive pollutants across water bodies associated with Phase 1 CSF Target Areas or all areas targeted consistently since Phase 1, for FIOs)

1. Introduction

The Catchment Sensitive Farming (CSF) partnership is an advice-led initiative delivering targeted support that enables farmers to take action to reduce water and air pollution. CSF's primary objective is to:

encourage voluntary action to help achieve Water Framework Directive (primarily for Protected Areas), National Emission Ceilings Directive and SSSI[3] targets.

This report reviews the effectiveness of CSF, against its water quality objectives, after twelve years of delivery. CSF's air quality objective was added in 2018 and progress will be assessed in a separate report.

CSF overview

Launched in December 2005, CSF contributes directly to Government targets for 'Clean and plentiful water' and 'Clean air' set out in the 25 Year Environment Plan (HM Government, 2018). It is delivered in partnership by Natural England and the Environment Agency.

CSF delivery includes:

- targeted and locally-tailored farm advice provided through a network of CSF Officers (CSFOs)
- facilitating delivery of Countryside Stewardship (CS) by bringing together land management and capital works to address water, alongside other, environmental objectives
- working with other advisers and partners, both locally and nationally, to extend the scale and scope of advice delivery and promote integration across organisations and initiatives
- specialist, private sector, farm advice procured through Natural England's Farm Advice Framework
- capital grants for farm infrastructure improvements, initially part of CSF but integrated within the multi-objective CS scheme since 2015
- evidence-led advice delivery informed through pollution risk assessment and local knowledge, including catchment steering groups
- robust monitoring and evaluation, driving continuous improvement of delivery

CSF has operated over four phases. Phase 1 ran from December 2005 to March 2008, Phase 2 ran to March 2011, Phase 3 to March 2014 and Phase 4 will run to March 2021.

CSF delivery is focused primarily within the CS High Priority Areas for Water, covering ca. 35 per cent of England. Prior to 2016, delivery was within CSF Priority Catchments which largely overlap the CS High Priority Areas for Water (Figure 1.1).

A full account of CSF is provided in a series of Delivery Reports (e.g. Natural England, 2019).

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[3] SSSI – Site of Special Scientific Interest

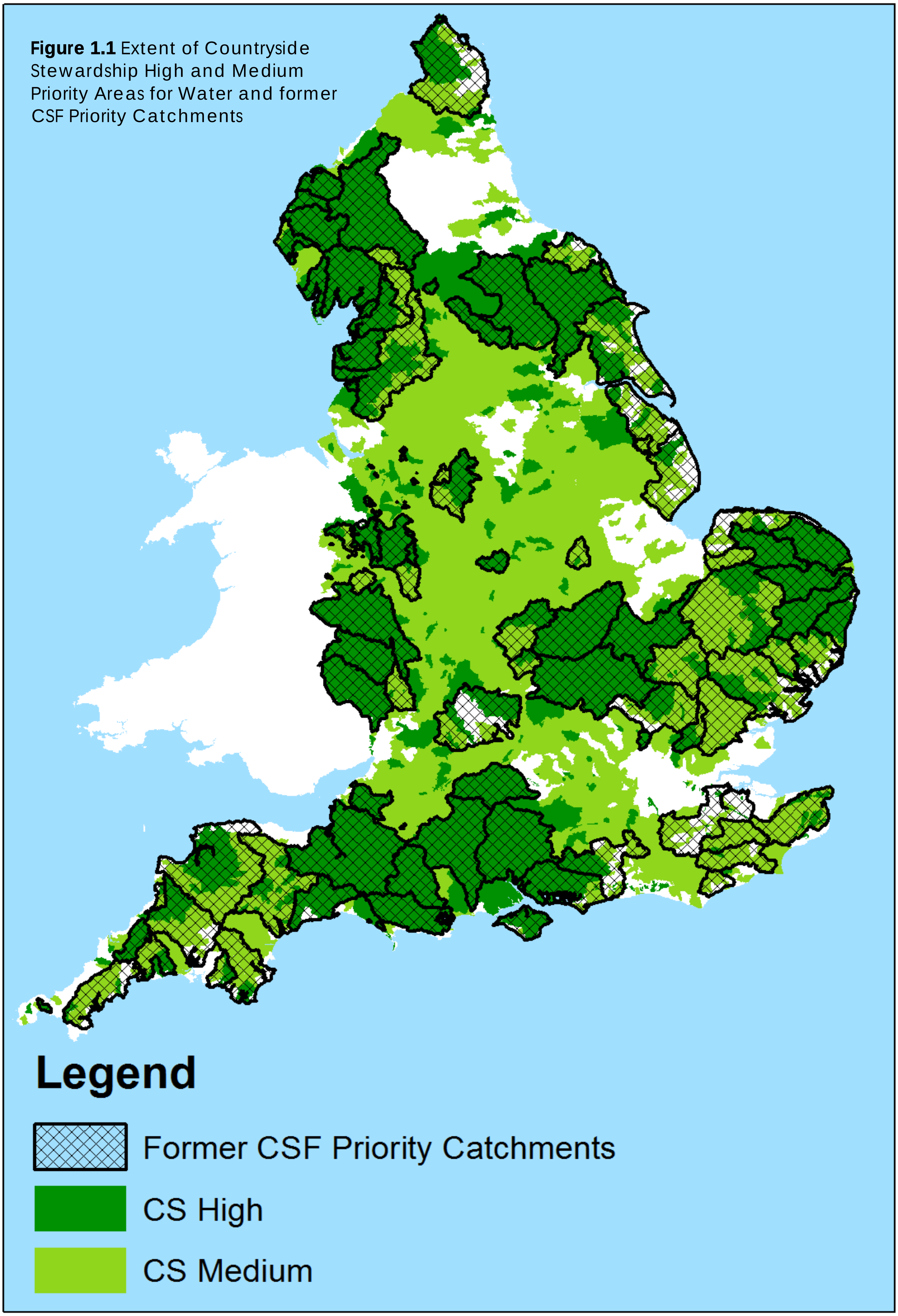


Figure 1.1 Extent of Countryside Stewardship High and Medium Priority Areas for Water and former CSF Priority Catchments

Evaluation design

Monitoring and evaluation are core elements of CSF. Evaluation informs decisions on the future of CSF, including ongoing improvement (of design and implementation) and reinvestment, as well as informing wider policy development. The role of monitoring and evaluation, as part of a process of continuous improvement, is formalised in the ROAMEF Cycle (Figure 1.2)[4].

There are substantial challenges to delivering a robust evaluation of a voluntary initiative, not least in understanding the processes through which voluntary advice translates into environmental outcomes. We designed our evaluation, where possible, to take account of, or exclude, complicating ('external') factors. These include the time lag before on-farm mitigation measures become effective and external influences, such as the weather and point source impacts on water quality.

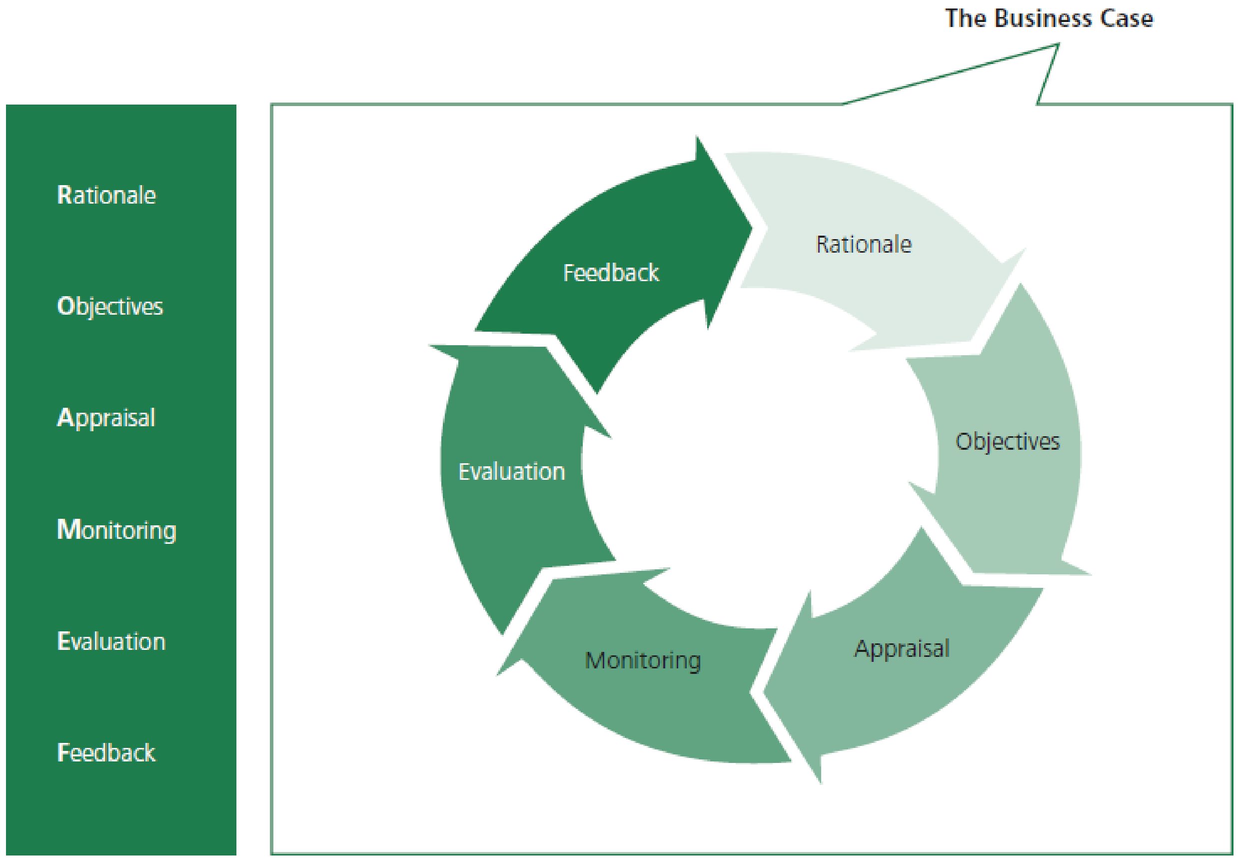


Figure 1.2 ROAMEF Cycle (HM Treasury, 2018)

[4] Economic evaluation is outside the scope of this report

Our evaluation includes information on both outcomes (*end effects*) and outputs (*activities*) based on a simple conceptual understanding of CSF. This is summarised in a *logic model* (Figure 1.3)[5]. It includes both behavioural and environmental assessments, recognising that the former have important impacts on environmental outcomes and, in particular, agreement holders' willingness to undertake environmental activities in the longer-term. When combined, we develop a weight of evidence that allows us to judge the overall success of CSF.

This report provides a summary of the evidence from our evaluation. Full details can be found in supporting technical reports, referenced in each section, and available on request from CSF.PMO@naturalengland.org.uk.

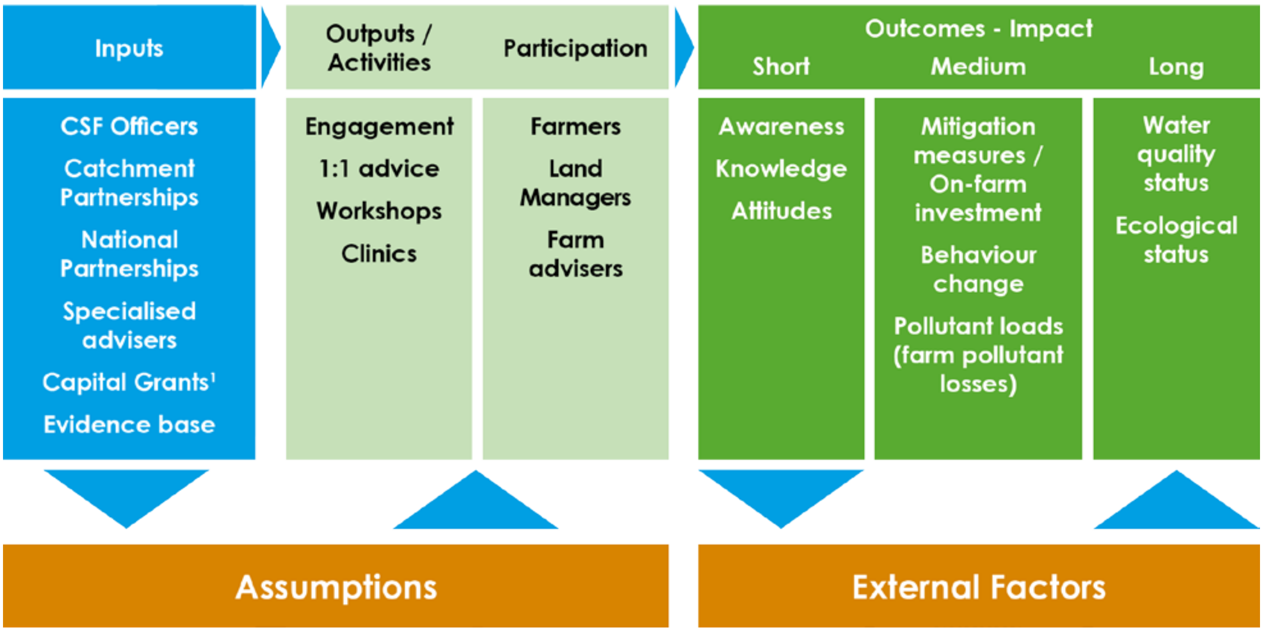


Figure 1.3 CSF logic model summarising a conceptual understanding of the links between CSF 'inputs', 'outputs' and 'outcomes' based on a range of underlying 'assumptions' and subject to the influence of a range of 'external factors'

[1] Initially through the CSF Capital Grant Scheme and subsequently through Countryside Stewardship and other Rural Development Programme schemes

[5] 'Inputs' are described briefly in the CSF overview (Section 1) and more fully in CSF Delivery Reports (e.g. Natural England, 2019)

2. CSF outputs

2.1 Farmer engagement and advice delivery

CSF has delivered extensive farmer engagement and advice delivery focused primarily on those parts of England where it is most needed.

The importance placed on building and maintaining effective relationships with the farming community is reflected in a high level of repeat farmer engagement.

CSF Officers have used a mix of one-to-one advice and group events to communicate advice effectively.

Evidence source: Environment Agency (2018a)

As of 19th January 2018, CSF advice had been provided to 23,512 farmers and land managers from 19,776 farm holdings, covering 3.3 million hectares. This represents 14 per cent of all farm holdings, and 34 per cent of the total farmed area in England[6]. Targeting of CSF advice to larger, potentially most-polluting, farms is reflected in the higher advice coverage by area than by holding number.

64 per cent of the CSF-engaged farmed area was within the CS High Priority Area for Water (CS High) reflecting CSF's primary focus on this area. 29 per cent was within the CS Medium Priority Area (CS Medium) and 7 per cent was within the CS Low Priority Area (CS Low). Delivery within the CS Medium and CS Low reflects a combination of historic targeting of CSF to Priority Catchments that included parts of these areas, land ownership that is spread across different priority areas, and some currently targeted delivery of partnership work within these areas.

Engagement covered 49 per cent of the total farmed area within the CS High, 23 per cent of the CS Medium and 17 per cent of the CS Low. It is important to recognise that CSF advice is targeted to the highest priority (potentially most-polluting) farm holdings. We are not aiming, or would not expect, to achieve 100 per cent engagement across the CS High through a voluntary initiative such as CSF.

Overall figures mask significant geographic variation at WFD Management Catchment and River Basin District scales (Figure 2.1). This reflects a wide range of factors, including: the duration of CSF advice activity, catchment size, holding size, and CSFO continuity.

Overall, 29 per cent of farm holdings have been engaged once through CSF, 18 per cent twice and 53 per cent on three or more occasions. This illustrates the importance placed on building and maintaining effective working relationships across the farming community in order to deliver CSF objectives.

CSF advice is delivered through a combination of one-to-one engagements, group events and clinics (for example at auction marts). Overall, 82 per cent of engaged holdings have received one-to-one advice, 57 per cent have been engaged through a group event and 5 per cent through a clinic.

[6] Based on all farms claiming Basic Payment Scheme payments in 2015

Group events provide a useful way of introducing farmers to CSF, before following-up with more holding-specific one-to-one advice. Delivered in partnership with other catchment initiatives, agronomy firms, environmental and industry bodies, group events also provide an effective way of linking up delivery at the catchment scale.

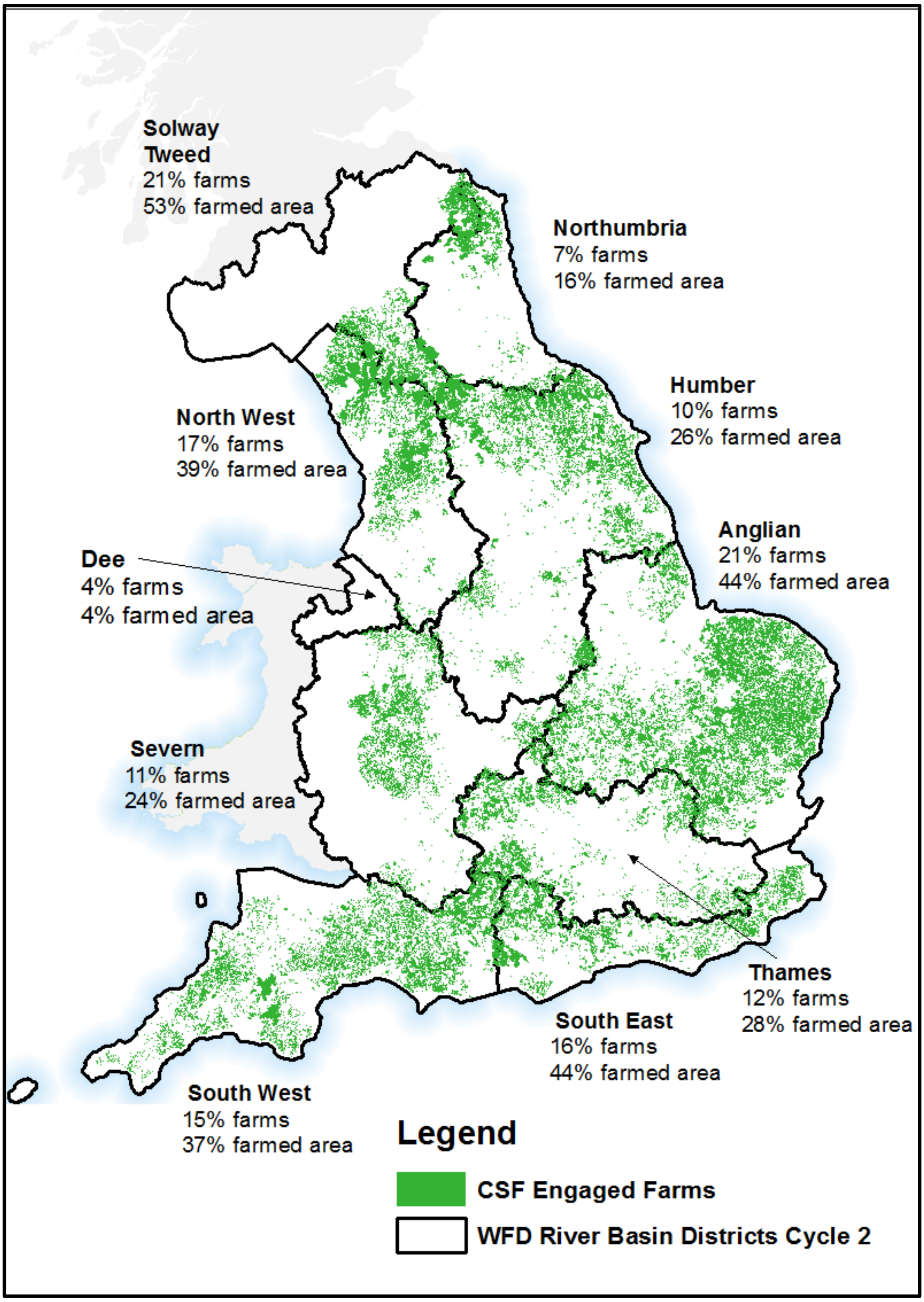


Figure 2.1 Extent of farm engagement across WFD River Basin Districts, expressed in terms of total farm numbers and total farmed area (Note: map shows full extent of RBDs, including areas within Scotland and Wales, but engagement statistics are for England only. There were no CSF Priority Catchments within the Dee RBD but the CSF High Priority Area for Water does overlap with parts of the south-east of the Dee RBD.)

3. CSF outcomes

3.1 Farmer awareness, knowledge and attitudes

There is a high level of awareness of CSF across the highest priority areas for action.

Farmer awareness and familiarity with CSF have increased understanding that farming contributes to water pollution and of the changes that can be made to reduce water pollution, and also correlate with an increased likelihood of farmers making these changes.

Evidence source: Ipsos MORI (2019)

Across the CS High, 67 per cent of farmers have had contact with, or have awareness of, CSF. Within the CS Medium the figure is 57 per cent. Although lower, as a result of CSF's primary focus on the CS High, this significant level of awareness reflects a level of both current and historical CSF targeting within the CS Medium, farm holdings split across CS boundaries, and the inevitable 'spill-over' of advice.

Our surveys highlight several features of CSF-engaged farmers:

- they have greater awareness of, or concern about, water pollution
- they are significantly more likely to have dealt with other agencies for help or advice to tackle the causes of water pollution (for example, 58 per cent have used or had dealings with three or more agencies, compared to 37 per cent of farmers across the CS High)
- those with small farms (10-100 hectares) are significantly less likely to have had contact with, or have awareness of, CSF

It is unclear to what extent this reflects the nature of the farmers engaging with CSF and/or the consequences of that engagement. Lower engagement of small farms is likely to result from a combination of CSF primarily targeting larger (potentially more-polluting) farms and the challenges of engaging small farms, as experienced for other schemes (Xavier et al., 2015).

Overall, farmers are very positive about their experiences of help and advice from CSF, with the vast majority agreeing they are satisfied (80 per cent of CSF-engaged farmers).

There is evidence that awareness of, and familiarity with, CSF increase farmers' recognition that farming contributes to water pollution. This is evident both in terms of agriculture's overall contribution, which the vast majority of farmers (91 per cent) accept, and in terms of farmers own farms' contribution, where, in general, they are less convinced. For example, one-third of farmers who are familiar with CSF say that agriculture contributes a 'great deal' or a 'fair amount' to water pollution in their area, compared to 26 per cent overall. Acknowledgement that activity on the farmer's own farm contributes at least a little to water pollution is significantly higher among CSF-engaged farmers, at 63 per cent (compared to 51 per cent overall)[7]. Past and future-

[7] The extent to which their personal farming activity contributes to water pollution was only asked of those who agreed that agriculture overall contributes 'at least a little' to water pollution in their local area.

planned action to address water pollution also correlate with the belief that a farmer's own farm contributes to water pollution.

Overall, farmers indicate they are well-informed about how they can help prevent or reduce water pollution in their area (for example, 85 per cent across the CS High). However, farmers who are aware of, or familiar with, CSF are more likely to feel very well or fairly well informed about the adaptations they could make to their farm in order to reduce water pollution (for example, 94 per cent familiar with CSF across the CS High). Farmers within the CS High who have met their CSFO are also more likely to feel informed (93 per cent).

Over 40 per cent of farmers in both the CS High and Medium report having made changes to their farm or the way that they farm in the last two years, that helped reduce water pollution. Significantly more CSF-engaged farmers (55 per cent) have made such changes.

Across the CS High and Medium areas, familiarity, awareness, and contact with CSF correlate with increased likelihood of making changes. In the CS High, having met a CSFO also correlates with being more likely to have made changes to reduce water pollution (60 per cent).

Among farmers who have made changes to their farm in the last two years, around seven in ten believe these changes have improved water quality at least a little. Around eight in ten farmers report at least one benefit from making changes including financial and reputational, as well as environmental, benefits.

3.2 Mitigation Measures / On-farm investment

241,925 individual mitigation measures have been advised through CSF.

The 128,691 measures advised through one-to-one farmer engagements have an overall implementation rate of 59.6 per cent.

Some measures are in the process of being implemented or are still being planned for whilst, for others, there are barriers to implementation (cost being most significant) or they are deemed no longer relevant.

Measures relating to the timing of fertiliser, manure and pesticide applications have the highest uptake rates, while those relating to farm infrastructure and land use change generally have the lowest.

Most advice implementation occurs within one year but in some cases it can take an extended period of time.

Both repeat advice and farmer understanding of how measures reduce water pollution are important in terms of measure implementation.

The majority of implemented measures are judged to be 'mostly effective', with effectiveness linked to farmers' understanding of how measures reduce water pollution.

The CSF Capital Grant Scheme was a strong enabler and driver of action to mitigate water pollution, and directly funded around 15 per cent of measures implemented (up to 2014).

CSF advice is making a positive contribution to the delivery of Countryside Stewardship objectives for water.

Mitigation measures

Evidence source: Environment Agency (2019a)

CSF provides advice to farmers on farm practice and infrastructure changes based on evidence of effectiveness as pollution mitigation measures. As of January 2018, a total of 241,925 individual pollution mitigation measures had been advised through CSF. This represents a 44 per cent increase since our last evaluation, reported in 2014 (Environment Agency, 2014).

A total of 127 different measures have been advised. The majority relate to soil management (25 per cent) fertiliser management (23 per cent) manure management (20 per cent) and farm infrastructure (16 per cent). Pesticide management (7 per cent) livestock management (5 per cent) and land use (1 per cent) were advised to a more limited extent[8].

[8] Some measures are effective across more than one of these categories

Although there was geographical variation, soil management, manure management, fertiliser management and farm infrastructure combined accounted for over 85 per cent of the total across all RBDs.

The advice provided was highly tailored to specific situations, but certain specific measures were widely advised. These included those relating to management of dirty water, soil and nutrient management plans, soil compaction and capping, livestock fencing, and farm tracks.

Implementation

Evidence sources: WRc (2016), WRc (2017), WRc (2019a)

We have undertaken annual assessments of the extent of implementation of mitigation measures advised through one-to-one farmer engagements since 2008/9. The latest assessment is reported in WRc (2019a). These assessments have been supplemented with analyses of the factors influencing advice uptake (WRc, 2017), why certain practices are implemented over others, the effectiveness of implementation, and farmers' understanding of how practices reduce water pollution (WRc, 2016).

Overall, 59.6 per cent (± 4.3 per cent at 95 per cent confidence) of 128,691 recommended mitigation measures have been implemented and 67.4 per cent (± 3.9 per cent at 95 per cent confidence) of farm holdings have implemented at least 50 per cent of recommended measures (WRc, 2019a). These figures have remained broadly consistent since the first assessment in 2008/9.

WRc (2017) used statistical regression models to explore why some measures are more likely than others to be implemented. Figure 3.1 shows the variation in typical implementation rates for the most commonly recommended measures. Fertiliser and pesticide management measures generally have the highest implementation rates. The four specific measures with the highest rates are aimed at reducing nutrient runoff, have no upfront costs and lead to either a cost saving or have low annual costs. Measures with the lowest implementation rates largely relate to farm infrastructure and manure management and typically have high upfront costs. Land use measures also have lower implementation rates despite their low or neutral costs, probably linked to low practicability / fit with the farm business.

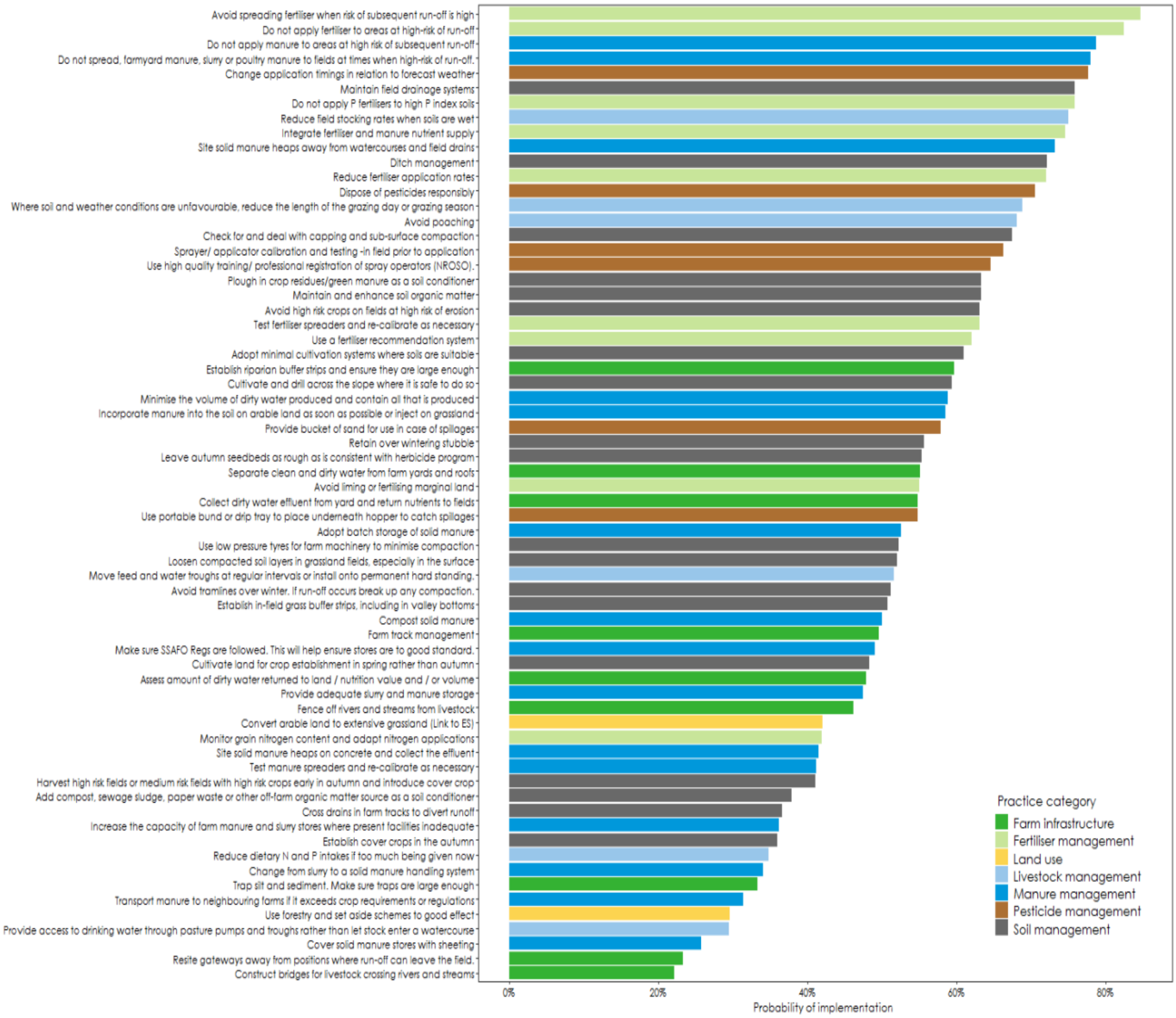


Figure 3.1 Implementation rates (probability of implementation) for commonly recommended measures (model output with other predictors at mid-range values)

Figure 3.2 illustrates the modelled effect of time since first recommendation (in years) on the probability of implementation and indicates that:

- the majority of implementation occurs within the first year following a recommendation (51 per cent in the case of soil management measures in the South West RBD)
- it can sometimes take an extended period of time for measures to be implemented, as illustrated by further incremental increases in implementation over time
- there is no evidence of any decline in implementation rates over a ten-year timescale

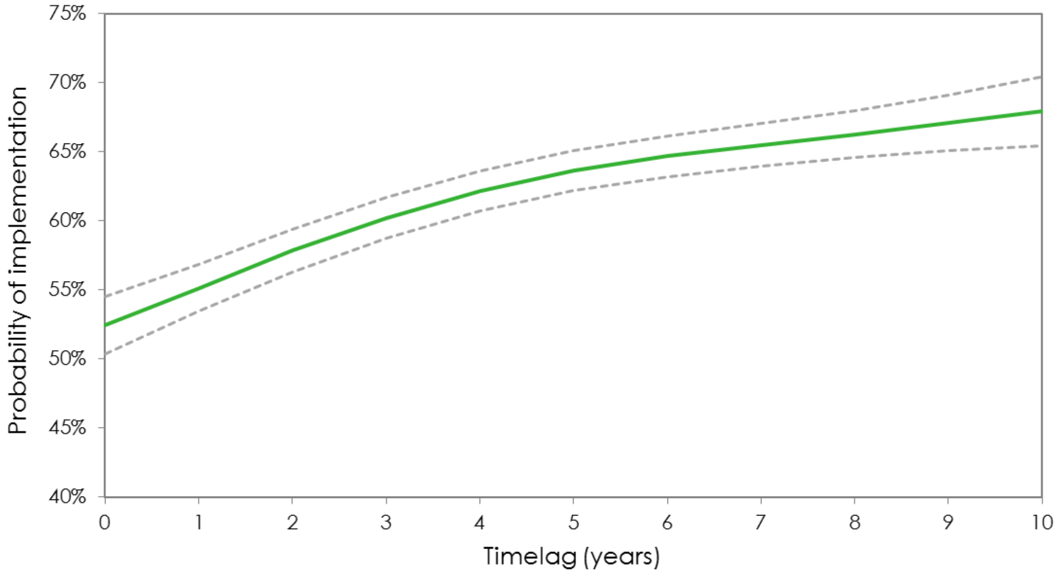
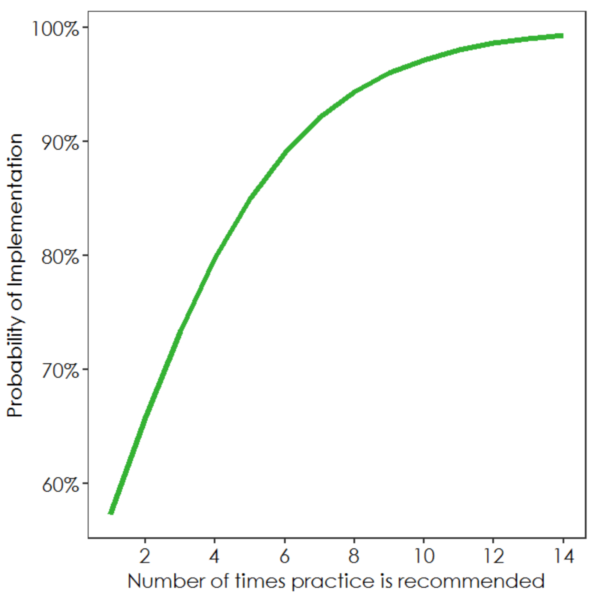


Figure 3.2 Effect of time since first recommendation (in years) on probability of implementation. The graph is for soil management measures in the South West RBD, although the shape of the relationship was the same across all RBDs. Measures assessed as being 'No longer relevant' (due to a change to the farm business, implementation of other practices eliminating their need, etc) were excluded. The dashed lines represent the standard error around the estimated implementation rate.

The WRc model quantified how the implementation rate is influenced by the number of times a specific measure is recommended at a specific farm. Based on the 2,572 (15 per cent) measures recommended more than once, Figure 3.3 shows a strong and statistically significant relationship indicating that repeat recommendations are associated with a higher probability of implementation. This finding should, however, be treated with caution as very few measures, within the audit dataset, have been recommended on more than three occasions.



Further analysis by WRc (2016) explored how far towards implementation recommended measures had progressed and the reasons why some had not (yet) been implemented. Figure 3.4 provides a breakdown for the ten most frequently recommended measures. The sample sizes for individual measures are small, but the breakdown indicates that cost is a barrier for measures that require upfront investment (i.e. farm tracks, manure storage and farmyard run-off management).

Figure 3.3 Relationship between number of times a specific measure is recommended at a specific farm and the probability of its implementation (model output with other predictors at mid-range values: South West RBD, advice from CSF Phase 2, derived from a single recommendation, and four years since first recommendation)

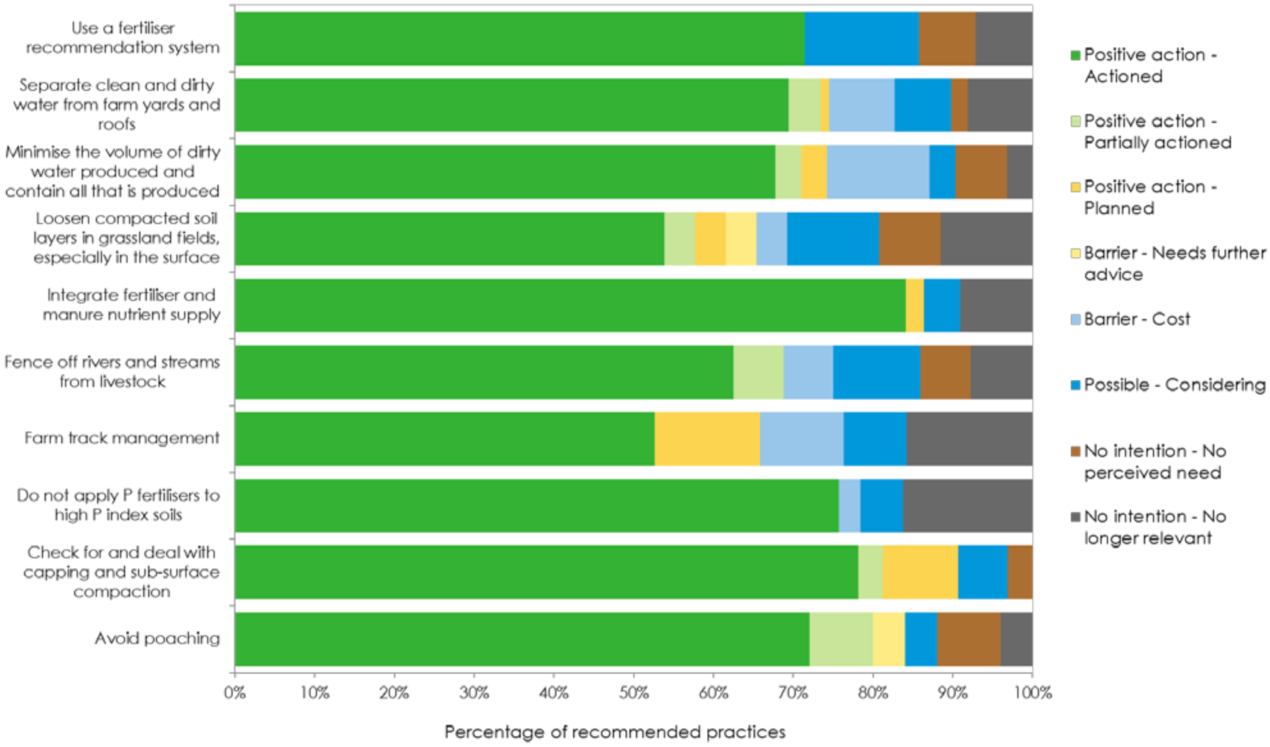


Figure 3.4 Mitigation measures categorised by level of action and reason for non-implementation

Farmers that had a better understanding of how a measure reduces water pollution were much more likely to implement that measure (Figure 3.5). Almost 90 per cent of measures recommended to farmers who had 'complete understanding' had been implemented, whereas no measures recommended to farmers with 'no understanding' had been fully implemented.

Unravelling cause and effect is difficult. It is likely that farmers will be persuaded to implement a measure once they understand its potential benefits, but it is also possible that understanding how a measure improves water quality is enhanced from first-hand experience implementing a measure. The very strong association observed between understanding and implementation is likely to reflect a combination of these influences. Nonetheless, this result appears to underscore the importance of education in driving behaviour change.

Overall, farmers reported an understanding score of 4 or 5 for 80 per cent of measures and a score of 1 or 2 for only 6 per cent of measures (where 1 equates to 'no understanding' and 5 to 'complete understanding'). This suggests that the advice delivered through CSF is successfully raising awareness of water pollution and how it can be mitigated.

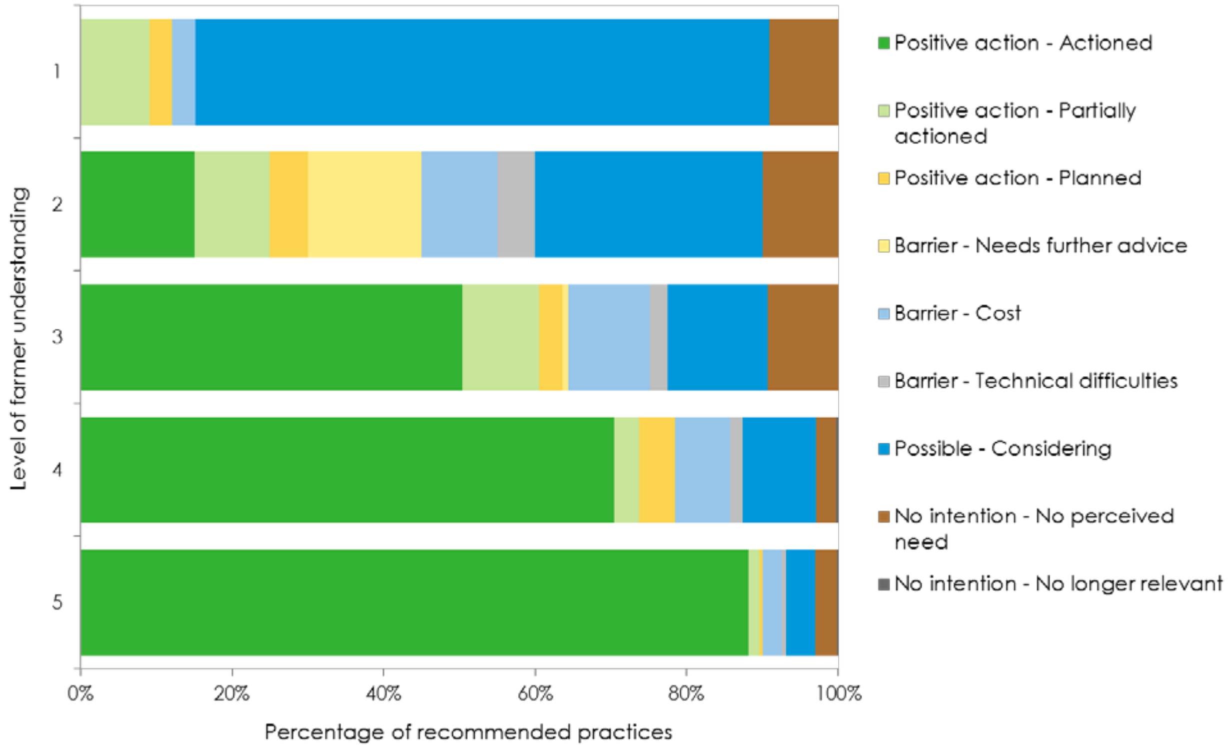


Figure 3.5 Extent of action and reason for non-implementation by level of farmer understanding (1 - no understanding to 5 - complete understanding)

The proportion of measures not implemented generally increased with cost, both upfront and annual cost (Figure 3.6).

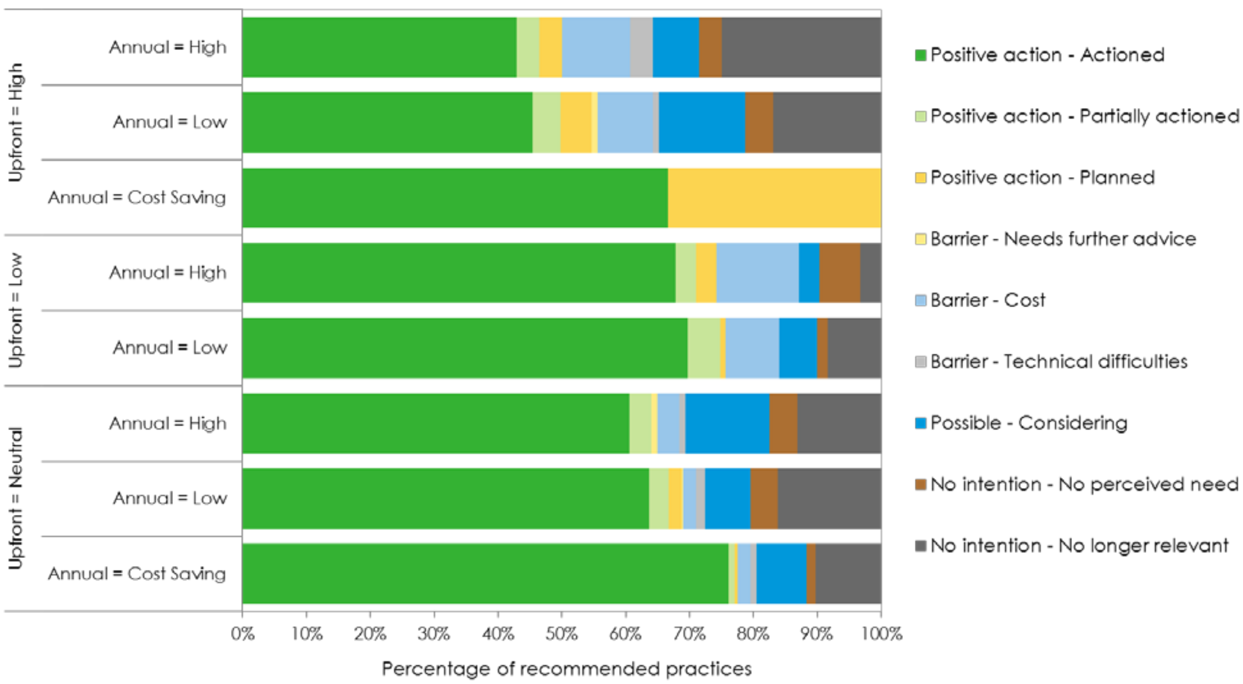


Figure 3.6 Extent of action and reason for non-implementation by level of cost (upfront and annual) (Note: only three practices had high upfront costs and annual cost-savings, so this category should be disregarded due to its small sample size)

The perceived effectiveness of implemented mitigation measures in reducing water pollution, based on a simple scoring system from 1 (completely ineffective) to 5 (fully effective) was assessed in WRc (2016). Overall, 52 per cent of measures were perceived to be 'fully effective' (score of 5) and 87 per cent were perceived to be 'mostly effective' (score of 4 or 5).

Where implementation was not completely effective, the main reasons identified were:

- limited impact - the measure was fully actioned, but made only a small or moderate contribution to reducing farm scale pollutant losses, or further measures were needed to provide a complete solution
- partial implementation – the measure had been implemented fully in some locations but not others
- inconsistent implementation – the measure was adopted most, but not all, of the time
- inadequate implementation – the measure had not been implemented properly, due to a lack of skills/knowledge/technique or poor equipment

Effectiveness of implementation was linked to farmer understanding of how a measure reduced water pollution. Over 80 per cent of measures implemented by farmers with complete understanding were rated fully effective, whereas fewer than 20 per cent were rated as fully effective where farmers had lower levels of understanding.

CSF Capital Grant Scheme

Evidence source: Environment Agency (2019a)

Between 2007 and 2014, the CSF Capital Grant Scheme (CGS) funded farmers to make relatively low-cost infrastructure improvements, within specific Target Areas of the former CSF Priority Catchments. The scheme funded £84M of improvements, a total match-funded by recipient farmers. A wide range of improvements were funded, although approximately 80 per cent of funding was for five items:

- yard works for clean and dirty water separation
- roofing of existing manure stores
- roofing for livestock gathering areas
- roofing for slurry and silage stores
- livestock and machinery tracks

There was clear variation across the RBDs in terms of both the scale and nature of CGS funding with most grants awarded in the South West (42 per cent, by value).

Overall, approximately 30 per cent of CSF-engaged farmers were CGS grant recipients, with 42 per cent of recipients receiving two or more grants (as of the end of the scheme in

2014). An estimated 15 per cent[9] of mitigation measures implemented following CSF advice, by this date, were directly attributable to the CGS.

Farmer surveys highlight the importance of the grant scheme as a strong potential enabler and driver of action to mitigate water pollution. The vast majority of farmers who received a CSF grant stated that it enabled them to make changes they would not otherwise have thought to make (91 per cent) or could not otherwise have afforded (90 per cent) (Ipsos MORI, 2015).

From 2015, the CSF CGS became part of the Countryside Stewardship scheme.

Facilitating Agri-Environment Scheme delivery

Evidence sources: Ipsos MORI (2019) unless stated otherwise

CSFOs play an important role in providing farmers with information on the availability of support for tackling water pollution, over and above that directly available through CSF. Our previous evaluation provided evidence of a slightly greater uptake of Entry Level Stewardship water options for agreements within, as opposed to outside, the former CSF Priority Catchments (Environment Agency, 2014).

With the launch of Countryside Stewardship in 2015, including more land management options and capital items for soil and water than previous schemes, the role of CSF in facilitating delivery of Agri-Environment Scheme (AES) objectives for water quality has strengthened. There is a good body of evidence demonstrating the effectiveness of this facilitation.

CSF-engaged farmers are more likely to have used or had dealings with Countryside Stewardship for support tackling the causes of water pollution. This includes 47 per cent of CSF-engaged farmers within the CS High and 43 per cent within the CS Medium areas.

The majority of farmers aware of CSF and CS agree that the CSF project's advice supports the CS scheme in achieving its water quality aims (76 per cent in CS High and 65 per cent in CS Medium). Greater knowledge of CS and an interest in reducing water pollution correlate with agreement that CSF supports CS in achieving its aims.

The important role of CSF advice is evident, with CSFOs being an initial point of contact for 40 per cent of successful Water Capital Only applicants, an important information source used to help complete applications (43 per cent) and cited as the main source of advice by 30 per cent (based on 2016 and 2017) (Short *et al*., 2018).

All farmers who had contact with a CSFO about a 2017 CS application found them to be very or fairly helpful (Ipsos MORI, 2019) and Water Capital Only applicants rated CSFO advice more influential than that from all other sources (Short *et al*., 2018).

Three in five farmers within the CS High, who have made, or are making an application to CS for water quality improvements, had contact with a CSFO in relation to their application.

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[9] Based on uptake of advice from one-to-one farmer engagements and implemented CGS options

Those in the CS High who have met their CSFO are significantly more likely to say they have funded changes through a CS Water Capital Grant (for example, 24 per cent compared with 11 per cent overall) and to have applied for a Mid-tier CS agreement (27 per cent compared to 14 per cent overall in the CS High)[10].

The influence of CSF has undoubtedly contributed to:

- holders of Water Capital Only agreements being the most positive CS agreement holders in terms of the effectiveness, outcomes, fit with the existing farming system and the advice and support received regarding options (Short *et al*., 2018)
- soil and water management options being among the most frequent scheme options and soil and water agreements accounting for the greatest share of annual scheme value (Jones *et al*., 2018)

3.3 Behaviour change

Farmers are very positive about their experiences of CSF and indicate CSFOs provide them with relevant and trusted advice. Most indicate working with their CSFO increased the priority they give to water pollution.

Holding-specific, one-to-one, advice is most effective for building trust and confidence. However, peer group interaction at group events is important for developing farmers' confidence and skills and establishing CSF as a good farming 'norm'.

Most farmers who make changes believe these changes make a difference to water quality in their local area (whether CSF-engaged or not).

A significant proportion of CSF-engaged farmers indicate they want to do more to reduce water pollution and a significant proportion are considering taking further action. CSF-engaged farmers are more likely to expect to see benefits from such changes.

Capital grant schemes have a strong impact on farmers' motivation to make further changes to reduce water pollution and to invest their own money.

Evidence source: Ipsos MORI (2019)

The 'quality' of farmer engagement with CSF and the outcomes of that engagement are important to the delivery of long-term, pro-environmental, behaviour change. Our evaluation provides evidence across a range of relevant aspects:

- farmer attitude, view of relevance and satisfaction with CSF engagement and advice
- farmer 'ownership' of water quality issues
- farmer experience of 'success'
- farmer motivation to remain engaged and continue positive management practices

[10] of those aware of both CS and CSF

- farmer motivation to deliver additional voluntary measures

Overall, farmers are very positive about their experiences of CSF, with the vast majority agreeing:

- the initiative encouraged them to reduce water pollution (95 per cent)
- the advice received was relevant to their farm (92 per cent)
- they received enough information to enable them to introduce new ideas or changes on their farm (89 per cent)
- they are satisfied with the help received (92 per cent)

It is clear that CSFOs meet the requirements for effective farm advisers with CSF-engaged farmers indicating their CSFO:

- had a good understanding of the issues relating to water pollution from farming activities (93 per cent)
- understood the needs of their farm (89 per cent)
- provided practical suggestions (87 per cent)
- was a person whose advice they could trust (95 per cent)
- was helpful and encouraging rather than telling them what to do (93 per cent)
- listened to them (93 per cent)
- provided them with new information (82 per cent)
- understood the range of grant mechanisms available for their farm (91 per cent)

80 per cent of CSF-engaged farmers indicated that working with their CSFO increased the priority they give to water pollution.

7 out of 10 farmers think the changes they have made are making a difference to water quality in their local area (whether engaged through CSF or not).

A significant proportion of farmers say they want to do more to reduce water pollution (49 per cent and 45 per cent across the High and Medium Priority Areas, respectively) with agreement significantly higher among CSF-engaged farmers (59 per cent). Across the CS High familiarity with CSF correlates with an increased likelihood of considering changes (24 per cent, compared with 19 per cent overall).

Similarly, 17 per cent of farmers across the CS High are considering making future changes to their farm or their farming practices to reduce water pollution, whilst 31 per cent of CSF-engaged farmers state this.

There is no suggestion that having made changes, farmers consider they have done all they can as, across all surveyed audiences, farmers who have made changes in the last two years are more likely to be considering further changes.

The most common changes under consideration by CSF-engaged farmers are:

- improving water storage or drainage systems (3 in 10)
- providing more coverage or roofing to farm yards (1 in 4)
- changing the way livestock are managed/housed and/or controlling access to water courses (1 in 4)
- creating field margins, buffer strips or barriers (1 in 6)

Significantly more CSF-engaged farmers (63 per cent) and CS High farmers (62 per cent) said they are 'very likely' to make the changes they are considering than those in the CS Medium (41 per cent).

Of those considering further changes, 31 per cent of the CSF-engaged farmers were prompted to consider these change(s) by CSF.

The proportion of farmers expecting to see benefits from future potential changes is significantly higher among CSF-engaged farmers (49 per cent) than in the CS High or Medium (37 per cent and 40 per cent, respectively). In all cases, the most commonly expected benefit from making future changes is better water quality (25 to 30 per cent).

Overall, one-to-one advice (as opposed to group events) is most effective, with farmers more likely to agree that:

- CSFOs understand the individual needs of their farms (94 per cent *vs*. 69 per cent)
- they receive enough advice to enable them to introduce new ideas or changes to their farm (84 per cent *vs*. 70 per cent)
- Officers help them overcome practical barriers to making changes (71 per cent *vs*. 49 per cent)
- they are satisfied with the advice received (92 per cent *vs*. 79 per cent)

A clear link is also apparent between one-to-one engagement and trust and confidence in CSF's effectiveness in tackling water pollution. 70 per cent of one-to-one engaged farmers state they have trust and confidence in CSF, compared to 50 per cent of those attending only group events (Ipsos MORI, 2014).

Group events do, however, provide a useful way of introducing farmers to CSF, before following-up with more specific one-to-one advice. Delivered in partnership with other catchment initiatives, agronomy firms and industry bodies, they also provide an effective way of linking up delivery at the catchment scale. Advice can also be promoted effectively in a practical farm setting where farmers learn from each other's experiences and visualise benefits in a tangible way (Fish, 2014). Such peer group interactions allow confidence and skills to be developed and help establish CSF as a good farming 'norm'. A mix of one-to-ones and group events, as practised within CSF, can therefore be seen as optimal for effective delivery.

Capital grants

Evidence source: Ipsos MORI (2015)

Ipsos MORI (2015) examined the impact of receiving a CSF capital grant on farmers' attitudes and plans to make further changes to their farming practices. Receipt of a capital grant motivated most farmers (79 per cent) to make or plan further changes to reduce water pollution. Further, 85 per cent of grant recipients indicated that receipt of a grant made them more willing to invest their own money in further changes. This was borne out to a fair extent in terms of these farmers actually having made changes funded by means other than CSF grants (55 per cent of all grant recipients and 72 per cent of multiple grant recipients). Amongst those who had made such changes, the most common funding sources were their own funds, business funds, or a loan (73 per cent). The important theme that emerges is that the availability of grant funding spurred recipients on to make further changes.

3.4 Pollutant loads (farm pollutant losses)

Mitigation measures advised through one-to-one CSF advice are estimated to have reduced total agricultural loadings of nutrients, suspended sediment, and FIOs by between 4.3 and 12.3 per cent across Phase 1 Target Areas.

Most CSF benefit is derived from a subset of mitigation measures and certain specific measures are disproportionately effective in reducing pollutant losses.

CSF Capital Grant Scheme options directly account for between 2 and 20 per cent of the overall pollutant reduction, depending on the specific pollutant, whilst farms receiving capital grants account for over 50 per cent of overall FIO and dissolved phosphorus reductions.

An estimated 1.6 to 8.2 per cent of the CSF pollutant reduction is from measures linked to agri-environment scheme options. There is strong synergy between the two, pollutant reductions being 4 to 8 times greater on farms implementing CSF advice as well as agri-environment options (compared to farms with agri-environment options only).

Evidence source: Environment Agency (2019b)

The overall impact of mitigation measures was modelled within the Catchment Change Matrix (CCM). This model links the agricultural mitigation measures to individual model farms representing each of the approximately 100,000 commercial farms in England. It combines measures implemented through one-to-one CSF advice to create total farm-scale pollutant reductions, based on measure-specific pollutant loss coefficients from Farmscoper v4 and then aggregates these to a variety of spatial scales. Based on advice delivery up to 1st January 2018, we modelled the impact of CSF on approximately 15,000 farm holdings, which equates to 90 per cent of farms receiving one-to-one advice[11].

[11] The remaining farms could not be linked to contemporary farms in the relevant Defra June Survey of Agriculture and Horticulture and could not therefore be modelled; for example, because they were not classed as commercial farms or following changes in land use and ownership

Agricultural pollutant losses

Using the Target Areas of Phase 1 Priority Catchments[12] (covering 11 per cent of England) and widely targeted pollutants as useful indicators of the benefit of sustained activity, CSF is estimated to have reduced annual agricultural pollutant losses by 4.3 per cent for nitrogen, 5.4 per cent for dissolved phosphorus, 8.0 per cent for total phosphorus, and 12.3 per cent for sediment. These summary figures mask significant variation. For example, while the overall dissolved phosphorus reduction is 5.4 per cent, a reduction of 10 per cent or more is estimated for 8 of the 40 Target Areas.

Where specifically targeted, the estimated average reduction for FIOs is 7.5 per cent, with reductions exceeding 10 per cent within certain catchments.

There is a clear relationship between the length of time CSF has been targeted to a specific area and the resulting pollutant reduction. This reflects a combination of the number of farms implementing CSF advice and the extent of uptake of mitigation measures on those farms, both of which increase over time. For example, sediment reductions across CS High Priority Areas (not formerly within CSF Priority Catchments) are 1.1 per cent, across CSF Target Areas (excluding Phase 1 Target Areas) they are 5.4 per cent, and within Phase 1 Target Areas 12.3 per cent.

Most effective measures

The most effective category of mitigation measure within CSF, a combination of efficacy and uptake, varies for the different pollutants. Soil management measures are most effective and contributed most to sediment (90 per cent), total phosphorus (60 per cent) and nitrogen (45 per cent) reductions. Farm infrastructure and livestock measures were most effective and contributed most to FIO reductions (50 and 41 per cent, respectively) manure and fertiliser management measures to dissolved phosphorus (40 and 28 per cent, respectively) and pesticide management most to pesticide reductions (88 per cent). Reductions from land use measures were low across all pollutants (ranging from less than 1 per cent for dissolved phosphorus to 7 per cent for nitrogen) due to their limited uptake.

At the individual mitigation measures scale, most CSF benefit is derived from a subset of all measures advised and certain specific measures are disproportionately effective, taking into account their efficacy and uptake within CSF. For example, the ten most effective measures account for over 80 per cent of the overall sediment reduction. The most effective measures (Appendix 1) are broadly similar to those identified in a similar study by Gooday et al (2015). Both analyses indicated 'establishing cover crops in autumn' as one of the most effective measures for nutrients and sediment and 'fencing rivers and streams' as the most effective measure for reducing FIOs.

CSF Capital Grant Scheme

Of the overall CSF pollutant reduction, between 2 and 20 per cent was directly attributable to Capital Grant Scheme (CGS) options, with the CGS contributing most to FIO and dissolved phosphorus reductions. This reflects the main emphasis of the CGS on pollutant sources associated with livestock as opposed to soil loss and fertilisers on arable land. As highlighted in Sections 3.2 and 3.3, the influence of capital grants goes well beyond the options they directly fund and this appears to be reflected in terms of overall pollutant load reductions. In particular, over half of the total estimated pollutant reduction for FIOs and dissolved phosphorus was from farms with CGS options.

[12] Target Areas were identified within Priority Catchments as the primary focus for CSF advice activity and capital grants

CSF and Agri-Environment Schemes

CSF has an important role in facilitating delivery of Agri-Environment Scheme (AES) objectives for water quality, as outlined in Section 3.2. Our modelling assessment provides valuable insight into the interactions between CSF and AES.

Across the pollutants, between 1.6 and 8.2 per cent of the overall CSF pollutant reduction is linked to measures within ES and/or CS agreements (i.e. AES land management options / capital items at the same specific farms) (Table 3.1).

Pollutant	Percentage of total CSF reduction from ES/CS measures
Dissolved phosphorus	1.6
Total phosphorus	2.1
Sediment	2.4
Nitrogen	3.0
E. coli	8.2

Table 3.1 Percentage of CSF modelled pollutant reductions associated with AES land management options / capital items

The links between CSF and AES are, however, stronger than these figures suggest. A significant proportion of the pollutant reduction resulting from AES (36.5 to 43.9 per cent, excluding that linked to CSF measures) is from farms that have also received one-to-one CSF advice and 17.3 to 27.2 per cent of the total pollutant reductions on farms receiving one-to-one CSF advice are from AES options / capital items (Table 3.2). Furthermore, pollutant reductions from farms with AES land management options / capital items are 4 to 8 times greater where these farms also engage with and implement CSF advice (Table 3.3). Although it is not possible to establish cause and effect these analyses confirm the strong synergy between CSF and AES.

Pollutant	Percentage of CS/ES pollutant reduction from CSF farms (excluding CSF measures)	Percentage of total pollutant reduction on CSF farms derived from ES/CS options
Dissolved phosphorus	36.5	18.5
Total Phosphorus	39.5	17.3
Nitrogen	43.9	27.2
Sediment	41.4	17.3
E. coli	39.7	21.5

Table 3.2 Percentage of AES pollutant reductions resulting from CSF farms (excluding CSF measures) and percentage of total pollutant reductions on CSF farms derived from AES schemes (land management options / capital items)

Pollutant	AES Only		AES Plus CSF	
	No. of Farms	Median Pollutant reduction (%)	No. of Farms	Median Pollutant reduction (%)
Dissolved phosphorus	23297	0.8	8261	5.4
FIOs (*E. coli*)	6110	0.9	6863	4.0
Nitrogen	23307	0.8	8264	5.0
Sediment	13058	2.7	7253	13.2
Total phosphorus	24140	0.9	8327	7.4

Table 3.3 Numbers of farms and farm-scale pollutant reductions for farms with AES scheme land management options / capital items only and AES scheme land management options / capital items plus CSF measures

3.5 Water quality

As a result of reduced pollutant loadings, water quality is estimated to have improved by between 1.2 and 6.5 per cent across water bodies associated with Phase 1 CSF Target Areas (for FIOs, all areas targeted consistently for this pressure since Phase 1).

These improvements are estimated to make a significant contribution to meeting *proportional* water quality targets for priority Bathing Waters, Natura 2000 Protected Areas, SSSIs and WFD water bodies.

Improvements in mean concentrations of orthophosphate, total phosphorus, *E. coli* and, to a lesser extent, suspended solids were evident from an analysis of water quality monitoring data. Total oxidised nitrogen and faecal streptococci improvements could not be detected in water quality monitoring data.

Nutrients, suspended solids and FIOs – modelling assessment

Evidence source: Environment Agency (2019b)

A bespoke HYPE[13] water quality model was developed to predict water quality improvements resulting from reduced farm pollutant losses (JBA, 2019; SMHI, 2018). Pollutant loads from the CCM were combined with point source discharge data to create the model, which was calibrated using water quality monitoring data. The model was simulated with and without estimated pollutant load reductions from CSF measures, to evaluate the impact of CSF on water quality concentrations.

From the HYPE model, CSF is predicted to have improved in-river nutrient, suspended solids (representing reduced agricultural sediment losses) and FIO concentrations by, on average, between 1.2 and 6.5 per cent, across water bodies associated with CSF Target Areas within Phase 1 CSF Priority Catchments (or all areas targeted consistently since Phase 1, for FIOs) (Table 3.4). The HYPE results show a similar pattern across the pollutants as for the CCM-modelled pollutant reductions, with the greatest improvement evident for suspended solids.

Pollutant	Median in-river pollutant reduction (%)
Dissolved phosphorus	1.2
Total phosphorus	2.4
Suspended solids	6.5
Total inorganic nitrogen	2.4
FIOs (*E. coli*)	1.3

Table 3.4 In-river pollutant reduction (expressed as a median) resulting from measures associated with one-to-one CSF advice (up to 1st January 2018) based on water bodies associated with Phase 1 CSF Target Areas (or all areas targeted consistently for FIOs since Phase 1)

[13] HYPE is an open-source semi-distributed Swedish hydrological water quality nutrient package, simulating water flow and pollution transport and transformation from precipitation, through soil, river and lakes to the river outlet. We worked in partnership with JBA and the **Swedish** Meteorological and Hydrological Institute to produce a new bespoke version in order to support the CSF initiative.

The relationship between the length of time CSF has been targeted to a specific area and the resulting improvement is also evident. Overall, pollutant reductions within Phase 1 CSF Target Areas are nearly twice as high as for those areas introduced in Phase 2 and over 10 times those for the new areas in Phase 4.

For all pollutants there are wide ranges in the scale of reduction (Appendix 2). Greatest reductions for total phosphorus, suspended solids and total inorganic nitrogen are in the same areas (including the Broadland Rivers, Hampshire Avon, Rivers Test and Itchen, South-east Kent, Dorset Stour, River Eye and River Wyre). For FIOs, greatest reductions are within the highest priority areas of the North West and South West.

At face value (putting aside all other influences) the modelled water quality improvements translate into the following water quality status changes[14]:

- 6 of 1,031 WFD river water bodies improve to Good Status for phosphorus (assessment limited to WFD water bodies with upstream CSF advice)
- 6 of 339 WFD river water bodies currently at Good Status for phosphorus improve to High Status (assessment limited to WFD water bodies with upstream CSF advice)
- 1 of 17 modelled Natura 2000 catchments (River Till (Tweed)) achieves the reduction calculated using the method outlined in the Improvement Programme for England's Natura 2000 Sites (IPENS) (Natural England, 2015)[15]

A more meaningful assessment of CSF is in terms of its *contribution* to meeting targets because CSF focuses solely on the agriculture sector and operates alongside other policy mechanisms. Sector-weighted, or proportional, targets were derived by dividing the 'gap' to target status by the relative source apportionment due to agriculture. Using this approach, CSF is making a significant contribution to delivering Protected Area, SSSI and WFD status targets. For example, our modelling indicates CSF delivery contributes, on average, to pollutant reductions equating to:

Phosphorus

- 14.2 per cent of the reduction required to meet the proportional WFD High Status target, with a significant contribution (greater than 25 per cent) to meeting the proportional High Status target in 50 water bodies (14 per cent of assessed water bodies)
- 7 per cent of the reduction required to meet the proportional WFD Good Status target, with a significant contribution (greater than 25 per cent) to meeting the proportional Good Status target in 41 water bodies (4 per cent of assessed water bodies)
- a greater than 25 per cent contribution to the reduction required to move 27 water bodies from Poor to Moderate and 3 from Bad to Poor WFD Status

[14] Models assume the benefits from mitigation measures are derived immediately - our wider evaluation suggests there is, in reality, a lag of several years
[15] There are no sediment targets equivalent to WFD and CSMG standards for phosphorus but developments in recent years have provided us with recommended sediment losses which we can use as 'targets' and assess the progress of CSF against.

- 14.2 per cent of the reduction required to meet the proportional Maximum Common Standards Monitoring Guidance (CSMG) target for assessed SSSI units, with a significant contribution (greater than 25 per cent) to meeting the proportional target in 9 SSSI units (12 per cent of those assessed)[16]
- 7.2 per cent of the reduction required to meet the proportional (more stringent) Near Natural CSMG target for assessed SSSI units, with a significant contribution (greater than 25 per cent) to meeting the proportional target in 6 SSSI units (5 per cent of those assessed)

Suspended solids/Sediment

- 11 per cent of the reduction required to meet the proportional proposed 'IPENS target' for 168 WFD water bodies where macro-invertebrate status is less than 'good', with the proportional 'target' being met for 14 water bodies and the reduction being greater than 50 per cent for a further 15 water bodies
- 43 per cent of the reduction required to meet the proportional proposed 'IPENS target' for 264 WFD water bodies where fish status is less than 'good', with the proportional 'target' being met for 32 water bodies and the reduction being greater than 50 per cent for a further 24 water bodies
- 44 per cent of the reduction required to meet the proportional proposed 'IPENS target' for 17 Natura 2000 catchments (with the River Clun estimated to meet the proportional 'target') and 19 per cent, on average, of the reduction required to meet the 'more stringent' proportional proposed 'IPENS target' for 20 catchments

FIOs (*E. coli*)

- 16.4 per cent of the reduction required to meet the proportional 'good' quality standard for 45 bathing waters that fail to meet the revised Bathing Water Directive standard and where CSF is predicted to reduce FIO losses from the upstream catchment, with a reduction of 50 per cent or more for 4 bathing waters
- 16.8 per cent of the reduction required to meet the proportional 'good' quality standard for 18 assessed bathing waters specifically targeted by CSF (within the CS High) with a reduction of more than 25 per cent for 4 bathing waters
- 5.5 per cent of the reduction required for 14 'good' quality bathing waters to meet the proportional 'excellent' quality standard

Nutrients, suspended solids and FIOs – monitoring assessment

Evidence source: WRc (2019b)

A Before-After-Control-Impact (BACI) approach was used to assess whether the reductions in farm pollutant losses from CSF measures could be detected in water quality monitoring data from downstream river sites.

The analysis was based on a network of water quality monitoring sites established in 2007 within, and broadly representative of, the former CSF Priority Catchments. Additional 'control sites' were also included. Six commonly monitored pollutants indicative of agricultural losses of nutrients, sediment and FIOs were assessed.

[16] The assessment included 121 distinct SSSI units and was based on the targets agreed for Natura 2000 sites as part of Ofwat's 2019 price review of water company charges

Building on previous evaluations (WRc, 2014) statistical regression models explicitly accounted for background changes in agriculture pressures and the uptake of measures through other (i.e. non-CSF) voluntary land management schemes and regulations. This addressed the risk that water quality benefits arising from CSF activity could be masked or exaggerated by concurrent changes in cropping patterns, livestock densities and farming practices, or be confounded with water quality improvements achieved via other policy mechanisms. Due to the lag period between a measure being advised and the resulting water quality response, the assessment was only able to fully evaluate the benefits of CSF advice delivered up to December 2015. Further water quality improvements can therefore be expected in the future from CSF advice delivered after 2015.

The analysis showed that the water quality response to reduced pollutant loading was highly variable across individual monitoring sites. This results from genuine differences in response to CSF measures, amplified by uncertainty around the magnitude and timing of CSF pollutant reductions and the imperfect ability of the statistical models to control for the confounding influence of local changes in both agricultural and non-agricultural pollution pressures.

Across the sites analysed, positive and negative biases can be expected to balance out making the overall, average, effect close to the truth. Figure 3.7 shows the estimated strength of the monitored water quality response to modelled CSF pollutant load reductions. A ‘response factor’ of 1 indicates that an X per cent reduction in (modelled) pollutant load leads to a corresponding X per cent reduction in mean (monitored) pollutant concentration, coefficients between 1 and 0 indicate a progressively weaker water quality response to reduced loading, and a coefficient of 0 indicates no water quality improvement at all.

For four of the six pollutants, mean concentrations at river monitoring points improved after CSF advice had reduced agricultural pollutant loads within the upstream catchment. The effect of CSF was strongest for orthophosphate, total phosphorus and *E. coli* and equated to improvements, relative to ‘control sites’[17], of 12 (3 to 20) per cent, 13 (4 to 21) per cent and 22 (4 to 35) per cent[18], respectively.

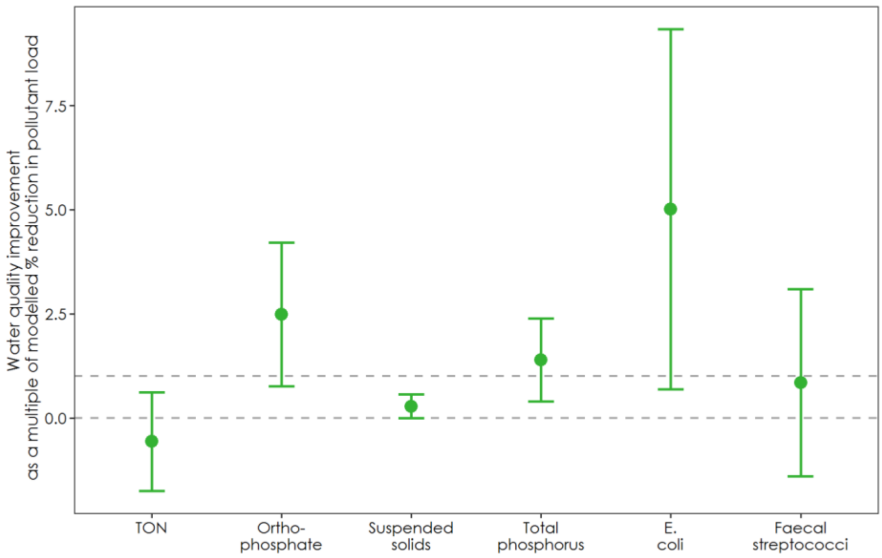


Figure 3.7 Estimated strength of monitored water quality response to modelled CSF pollutant load reduction, assuming a three year lagged response (Note: dashed lines correspond with ‘response factors’ of 0 and 1).

[17] Monitoring sites with no upstream CSF measures / modelled pollutant load reduction
[18] 95 per cent confidence intervals quoted in parentheses

In all three cases, the degree of water quality improvement was greater than the load reduction predicted by the CCM model. The confidence intervals around the results were wide, however, and there is no clear evidence that the water quality response is disproportionate to the magnitude of the load reduction. The variation in response at an individual site level is illustrated in Figure 3.8a, for orthophosphate.

The improvement was weaker (and only marginally statistically significant) for suspended solids, the mean 5 per cent (0 to 9 per cent[19]) reduction in concentration being less than half the modelled percentage reduction in load. This may be because bank erosion and re-mobilisation of in-stream sediment attenuate the effect of reductions in agricultural sources. The variation in response at an individual site level is illustrated in Figure 3.8b.

No significant water quality benefit was found for total oxidised nitrogen (TON) or faecal streptococci. CSF was predicted to have reduced TON loading by between 5 and 18 per cent at 20 sites but few sites exhibited a positive water quality response. In the case of faecal streptococci, the estimated ‘response factor’ was close to 1 (0.84) but successive sample measurements were highly correlated, reducing the power of the model to detect a statistically significant response. Nonetheless, the consistent response observed across 20 monitoring sites suggests faecal streptococci concentrations may have improved as a result of CSF activity.

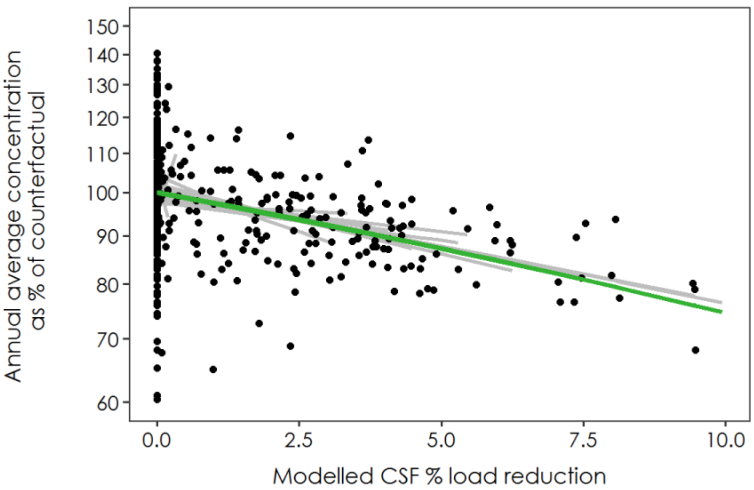
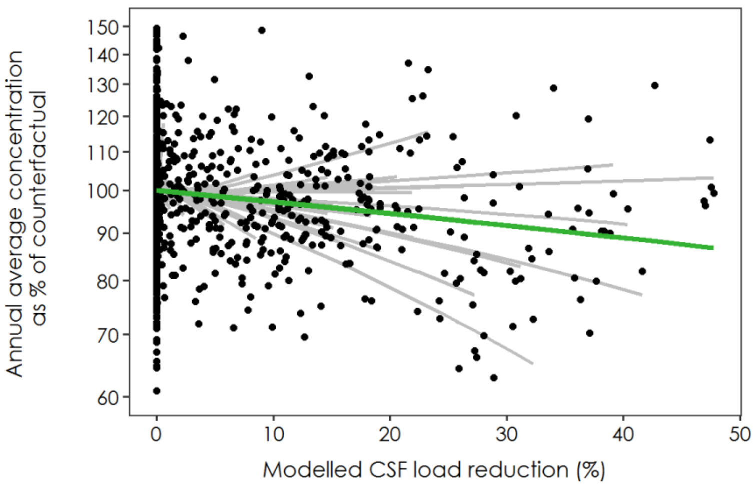


Figure 3.8 Association between modelled CSF pollutant load reduction and observed concentration at individual sites (grey lines) and across all sites (green line) for (a) orthophosphate and (b) suspended solids (for clarity, individual water quality sample measurements have been aggregated to annual



[19] 95 per cent confidence intervals quoted in parentheses

Pesticides

CSF has delivered reductions in pesticide levels across four monitored river catchments. Taking the first three years as a baseline, the mean of the subsequent nine years was 34 per cent lower in terms of the proportion of samples exceeding a 0.1µg/l threshold. This improvement has been achieved against the backdrop of variable climatic conditions, crop management issues, and overall increases in cropped arable area and pesticide use.

Evidence source: Environment Agency (2019c)

Pesticide monitoring data are highly variable, reflecting a complex mix of controlling factors. However, across four catchments with surface water drinking water abstractions and where we have monitored pesticide concentrations since 2006, water quality monitoring data show the overall positive benefits of CSF. Benefits become clear after about three years of CSF activity. This follows inertia in the system related to engagement building and the conversion of advice and grants into implemented actions.

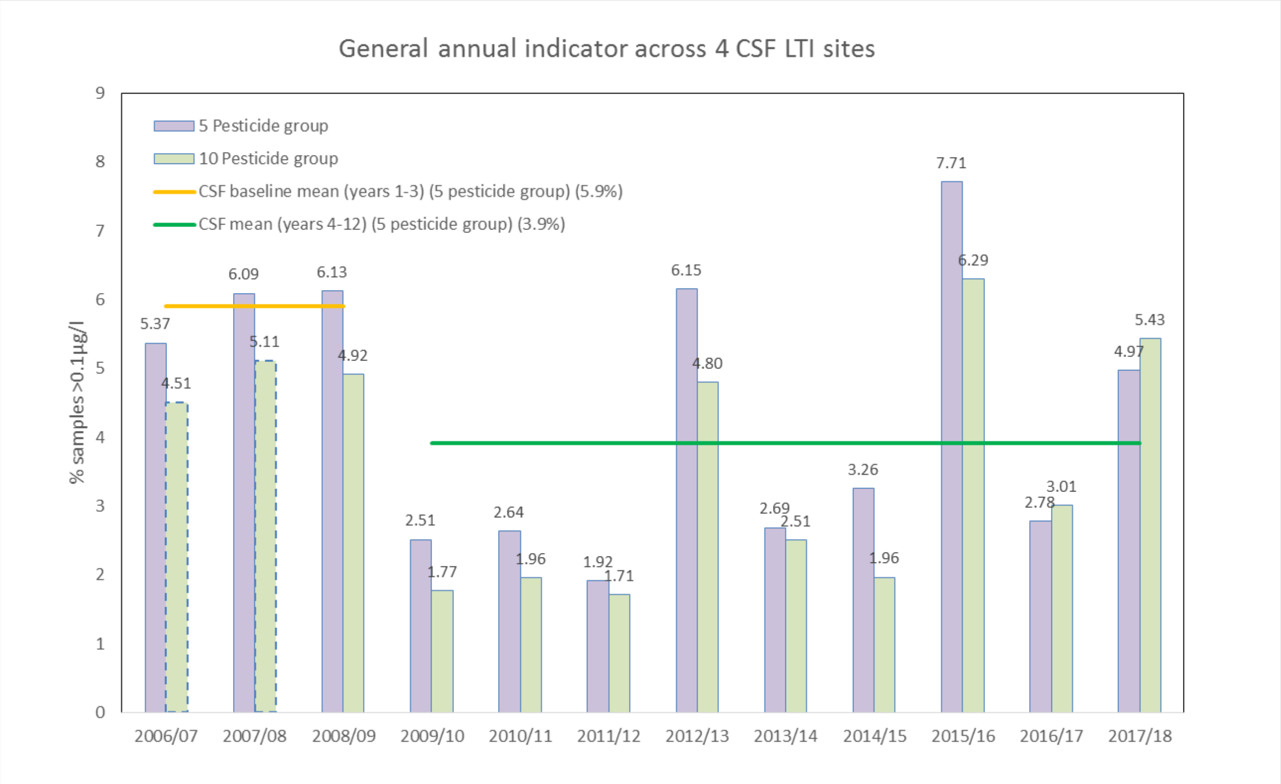


Figure 3.9 Combined high level indicator for 5 and 10 'indicator' pesticides across four river catchments (data for 5 of the 10 pesticides were not available for 2006/7 and 2007/8 - that presented is based on extrapolation from the 5 pesticides)

Across a set of 'indicator'[20] pesticides, the mean of the last nine crop years is 34 per cent lower than the baseline, in terms of the proportion of samples exceeding a 0.1µg/l concentration threshold (Figure 3.9), 45 per cent lower in terms of annual average concentration, and 36 per cent lower in terms of annual river load[21]. In any one year, reductions from the baseline vary significantly, for example from a 68 per cent reduction to a 31 per cent increase in terms of the proportion of samples exceeding 0.1µg/l. However, in six of the nine 'post-CSF' years reductions of the order of 50 per cent are apparent.

The overall improvement has been achieved against the backdrop of a 9 per cent increase in the arable crop area and a 20 per cent increase in use of the indicator pesticides, across the four monitored catchments, both of which act contrary to efforts to improve river quality. In contrast, average river flow across the four catchments was 12 per cent higher for the three baseline years compared with the subsequent nine years, and this will have contributed to the improvements in pesticide levels.

Annual data summaries mask the strong seasonal element to pesticide occurrences resulting from crop patterns and pesticide usage periods. Figure 3.10 compares the 'baseline' (2006/7 to 2008/9) and 'post-CSF' (2009/10 to 2017/8) time-periods on a month-by-month basis and shows the significant monthly variation. A consistent reduction is evident across the whole year with a mean monthly reduction of 37 per cent (range 8 per cent to 65 per cent). The reduction varies from month to month, being highest in the autumn and winter months. This is likely to reflect a combination of CSF measures being more effective against sources of pesticides most prevalent in winter (reducing over-land flow from fields or pesticide losses in drainage, for example) and a focus on the issue of autumn-applied oil-seed rape herbicides. Importantly though, the data show that CSF has improved pesticide levels throughout the year and across a range of different pesticides and farming sectors.

In addition to regular seasonal patterns, pesticide 'events' occur. These can be caused by storms, but they are also strongly linked to operational activities at any time of the year and also to seasons that are particularly challenging for crop production (for example, associated with delayed oil-seed rape growth in spring 2013). Such events can override general catchment improvements, confirming that CSF will not eradicate pesticides from rivers. Our monitoring indicates that the changes brought about by CSF result in a reduced frequency and duration of peak concentrations of the monitored pesticides. The risk of 'exceedences' of the 0.1µg/l threshold remains, however, for all of the indicator pesticides in all of the test catchments in any particular year.

[20] The indicator pesticides are among the most frequently occurring pesticides in previous river monitoring studies and represent pesticide use on a range of arable and grassland crops: 2,4-D, bentazone, carbetamide, chloridazon, ethofumesate, fluroxypyr, MCPA, mecoprop, metazachlor, and propyzamide.

[21] For the purposes of comparing river loads the 2012/13 crop year was excluded from the analysis. Spring 2013 saw an extreme weather and flow event especially in East Anglian catchments (e.g. 1:30 years in the Waveney) with associated pesticide loads. The extreme load measured in March 2013 dwarfs the other loads and dominates any analysis of underlying trends or changes.

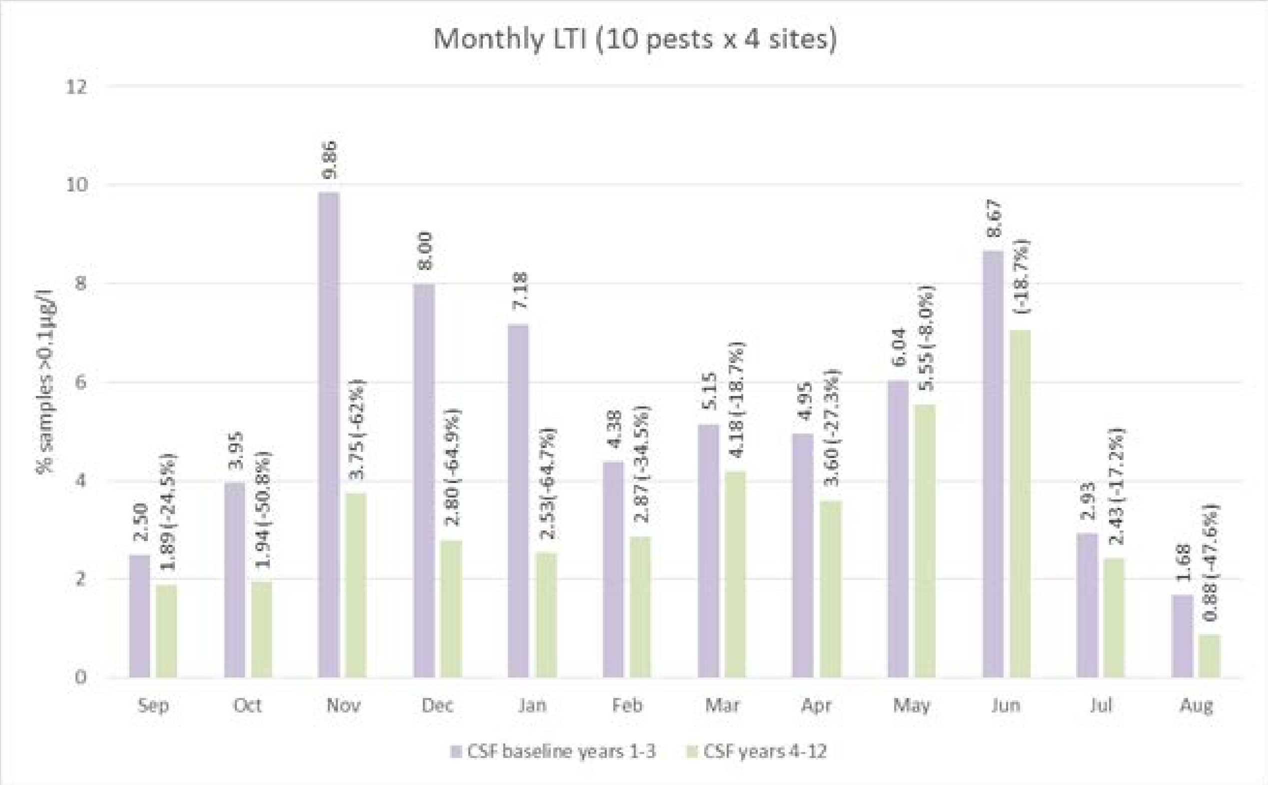


Figure 3.10 'Baseline' and 'post-CSF' summary by month for a composite of 10 pesticides across four river catchments

3.6 Ecology

No statistically significant improvement in ecological quality metrics was evident following reductions in agricultural pollutant losses associated with CSF advice delivery.

However, the strong association between macro-invertebrate metrics and agricultural pollution pressure indicates that further reductions in pollutant loadings can be expected to lead to ecological improvements over the longer-term.

Evidence source: WRc (2019c)

Using a similar statistical approach to that for nutrient, suspended solids and FIO monitoring data (Section 3.5) an assessment was undertaken to see if the reductions in farm pollutant losses from CSF measures could be detected as improvements in ecological monitoring data at downstream river sites.

The analysis was based on 279 macro-invertebrate and 102 diatom Environment Agency monitoring sites that have long-term monitoring records and are not unduly influenced by non-agricultural point source pollution. Three metrics, expressed as Environmental Quality Ratios[22] to factor out natural ecological variability, were assessed:

[22] based on observed data and site-specific reference values predicted from physical and chemical parameters

- Average Score Per Taxon (ASPT)[23]
- Proportion of Sediment-sensitive macro-Invertebrates (PSI)
- Trophic Diatom Index (TDI)

ASPT and TDI are WFD metrics, reflecting overall pollution and trophic status, respectively. PSI reflects sedimentation impacts (Extence et al., 2013).

Ecological metrics were compared before and after CSF advice delivery across monitoring sites that varied in the extent and timing of upstream advice delivery. Statistical regression models explicitly controlled for potentially confounding changes in pollution pressure caused by changes in cropping patterns and livestock densities, uptake of land management measures delivered via other (non-CSF) voluntary and regulatory schemes, and seasonal and flow-driven variation in ecological quality.

Overall, after controlling for confounding factors, none of the three metrics improved significantly following CSF-driven reductions in agricultural pollutant losses within upstream catchment areas. PSI and ASPT showed only marginal improvements, even at sites with the largest percentage reductions in sediment loading due to CSF, and TDI deteriorated slightly, on average.

The lack of evidence for an ecological response indicates that the impact of CSF is currently too small to stand out from the influence of other anthropogenic pressures and natural processes. In particular, the assessment of CSF is against a backdrop of considerable site-specific variation and an underlying, long-term, trend of improving ecological status (as also noted in other studies). In addition, the analysis was hampered by an overall lack of monitoring sites in rural areas that are not impacted by small point source discharges and that represent a range of CSF activity levels, as well as by the limited ecological monitoring data at suitable sites (mean of 12 macro-invertebrate and 5 diatom samples per site).

While no significant relationship was found between the ecological metrics and CSF-driven reductions in agricultural pollutant loads, there was a strong association between the macro-invertebrate metrics and agricultural pollution pressure. This indicates that although any ecological change is too small to detect at present, further reductions in pollutant loadings can be expected to lead to ecological improvements over the longer-term.

[23] calculated using the Whalley, Hawkes, Paisley & Trigg method (WFD-UKTAG, 2014)

3.7 Groundwater

There is some evidence that trends in groundwater nitrate concentrations have improved since CSF was launched. This analysis was based on aquifers considered most likely to show early changes. It did not, however, provide clear evidence that the changes were attributable to CSF.

An advanced statistical modelling approach has now been developed that looks to make full use of all available monitoring data. Looking forward, we aim to develop this into an operational method to assess the groundwater benefits of CSF.

Evidence sources: AMEC (2014a), AMEC (2014b), Barnes et al. (2018)

Our previous CSF evaluation provided some evidence of improved groundwater quality within CSF Priority Catchments. A reduction in the number of monitoring points with increasing nitrate trends and an increase in the number showing decreasing trends, was evident post-CSF implementation. This was based on analyses of nitrate in low matrix and high fracture permeability aquifers and baseflow-dominated surface waters (Amec, 2014a; Amec, 2014b). It did not, however, provide clear evidence that the changes were attributable to CSF.

Barnes et al. (2018) subsequently assessed the feasibility of using advanced statistical modelling, informed by hydrogeological understanding, to quantify the national-scale effects of CSF on groundwater quality. The study looked to make full use of available data, including that from outside of CSF catchments, given that changes within CSF catchments could have been associated with broader trends unrelated to CSF. A statistical model was formulated to incorporate modelled changes in catchment loadings into a national-scale analysis of spatial and temporal trends in groundwater pollutants.

The study provided a proof-of-concept for the methodology demonstrating that modelling results are relatively insensitive to a range of plausible modelling assumptions and data processing decisions. Looking ahead, we aim to develop this approach into an operational method that incorporates additional data on borehole depth and catchment nitrate loading histories, as well as additional post-CSF groundwater monitoring data.

3.8 Pollution incidents

A high-level analysis suggests CSF has reduced the occurrence of 'serious' water pollution incidents in Phase 1 and 2 CSF Target Areas where advice delivery has been most focused. Across areas where there are agricultural pressures but less CSF advice delivery numbers of pollution incidents have increased.

Evidence source: Environment Agency (2019d)

Agriculture is responsible for around 20 per cent of all 'serious'[24] water pollution incidents (excluding waste incidents) and around 50 per cent of agricultural incidents are linked with the dairy sector . While CSF does not have a direct role in enforcing environmental legislation, we might expect fewer incidents following CSF advice delivery, for example, because CSF-engaged farmers are more aware of, and have taken steps to minimise, water pollution.

Assuming 2006-9 represents a 'pre'-CSF scenario (see Section 3.5) Figure 3.11 shows the annual average number of serious agricultural incidents (standardised by agricultural area) across the Phase 1 and 2 CSF Target Areas, the Phase 1-3 Priority Catchments (excluding the Phase 1 and 2 Target Areas) and areas outside of CSF Priority Catchments. Numbers of incidents per unit area were lowest in areas outside of CSF in the pre-CSF situation, which would be logical as the CSF areas were identified as being higher risk areas in terms of agricultural pollution. 'Post'-CSF, the annual number of incidents per unit area decreased within the Phase 1 and 2 Target Areas (by 17 per cent) and increased in the wider CSF Priority Catchments (by 22 per cent) whilst changing little outside of CSF (1.5 per cent decrease). This analysis suggests CSF is reducing agricultural pollution incidents where CSF delivery has been most focused, but incidents are increasing in areas where there are agricultural pressures but less focused CSF advice delivery.

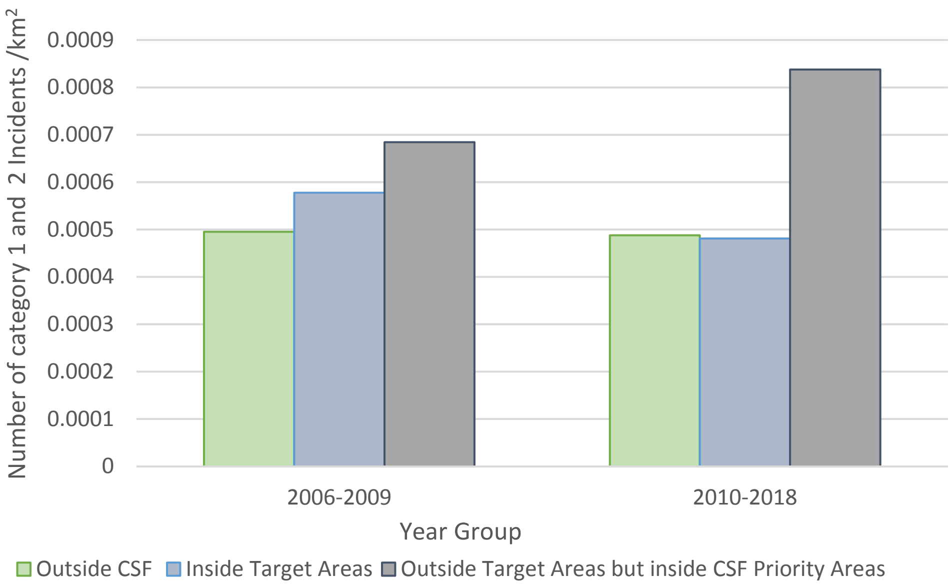


Figure 3.11 Serious pollution incidents (per Km²) across Phase 1 and 2 CSF Target Areas, Phase 1-3 Priority Catchments (excluding the Phase 1 and 2 Target Areas) and areas outside of CSF Priority Catchments, over 'pre'- and 'post'-CSF time periods

[24] A combination of Categories 1 (major effect) and 2 (significant effect) within the Environment Agency's Common Incident Classification System

Analysis of Variance indicated there was a statistically-significant difference between the number of incidents per unit area across the three areas and 'pre'- and 'post'- CSF time periods. Significant differences were not found between all combinations of area and time periods, however, as a result of the high underlying annual variation in numbers of pollution incidents.

3.9 Natural Capital

CSF helps maintain a wide variety of natural capital through advice that is distinct from that provided by other farm advisers.

Benefits particularly associated with CSF include: clean water, biodiversity, provision of animal products and materials, erosion control, reduced flood risk, natural pest control, and beneficial insect pollination.

Evidence sources: WRc (2012), Vrain & Lovett (2019)

WRc (2012) previously used an ecosystem service approach to demonstrate that mitigation measures implemented through CSF deliver benefits that go well beyond improving water quality. Although water quality impacts were the single largest benefit, they accounted for a small minority of the total ecosystem service benefit. In addition, a small number of measures were shown to contribute disproportionately. The top five measures together accounted for 42 per cent of the total impact of CSF: cultivate compacted tillage soils, in-field buffer strips, do not apply phosphorus fertiliser to high index soils, riparian buffer strips, and use of a fertiliser recommendation system.

A recent review by Vrain and Lovett (2019) framed CSF benefits in terms of their contribution to maintaining and enhancing natural capital. The Natural Capital Committee (2014) defined natural capital as 'the elements of nature that directly or indirectly produce value to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions'. The CSF assessment was informed using natural capital logic chains (Natural England, 2018) that summarise the relationships between ecosystem assets, ecosystem service flows and benefits to society, as well as relevant management interventions and other drivers of change.

The review concluded that CSF helps maintain a wide variety of natural capital, although a monetary assessment was not possible given the limited available monetary valuation data. CSF contributes to ecosystem assets across many types of habitat, with a particular focus on water quality, soils, crop and livestock production, pest and disease control, climate regulation, and maintenance of nursery populations and habitats. The benefits particularly associated with CSF include clean water, biodiversity, provision of animal products and materials, erosion control, reduced flood risk, natural pest control, and beneficial insect pollination. CSF advice was shown to be distinct from that provided by other farm advisers, including environmental non-government organisations, agricultural industry and government. The mitigation measures providing the greatest range of natural capital benefits were those related to woodland creation, land drainage, management of livestock grazing/trampling, and pesticide use.

The review identified a number of areas where the role of CSF could potentially be broadened to help sustain other elements of natural capital: water supply management, precision farming (to enhance resource-use efficiency) and reducing carbon emissions / improving air quality. The integrated delivery of water quality and quantity advice is currently being piloted within CSF.

4. Continuous improvement

There is a strong history of using evidence and evaluation to shape delivery of CSF and drive continuous improvement. Examples include:

- targeting CSF delivery to geographic areas where mitigation of agricultural impacts will be most beneficial (most recently through the CS targeting process)
- prioritisation of farm holdings for advice delivery, based on modelled loadings of pollutants relevant to catchment-specific water quality issues
- using remote sensing to help locate mitigation measures effectively within the landscape
- maintaining a strong link between advice delivery and capital grants, to maximise the benefits from both
- regular provision of pesticide water quality monitoring data to CSFOs (as well as wider catchment schemes) to target and refine advice delivery

During the remainder of Phase 4 we will use the evidence from this evaluation to inform the development of further decision support tools and guidance, providing:

- catchment-specific breakdowns of the relative contribution of different farm pollution sources (for example, soil, fertiliser and manure losses from arable, grassland and farm yards) and identifying the potentially most effective mitigation measures for implementation through CSF
- estimates of future likely water quality benefits from the potential application of CSF, or similar approaches, to 'new' geographical areas
- effective catchment-scale approaches for tackling pesticide issues alongside other pollutants

CSF evidence also delivers, or has the potential to deliver, benefits over a wide range of policy areas and issues:

- provision of a long-term national river quality surveillance monitoring network (sampled at relatively high frequency) for nutrients, suspended solids, pesticides (including 141 current plant protection products or around 47 per cent of those currently approved for use) and other chemicals (for example, pharmaceuticals)
- informing policy options appraisals through evidence of the effectiveness of farm advice
- providing an effective framework for evaluating other policy mechanisms alongside CSF (for example, evaluating water quality objectives of agri-environment schemes, Farming Rules for Water, and regulatory pesticide bans)
- developing land use, pollutant transport and daily time-step water quality models and modelling capability
- informing the design and delivery of catchment management schemes – defining outcomes / success measures, catchment characterisation, stakeholder engagement, monitoring strategies and evaluation frameworks
- demonstrating the benefits of effective policy evaluation

5. Conclusions

Evaluation is essential to support continuous improvement and inform decisions on future investment in the CSF partnership. This report provides a robust evaluation of CSF. It presents clear and compelling evidence that CSF is delivering improvements in water quality that contribute to achievement of WFD and SSSI targets. CSF is, however, part of a wider policy mix and, in the majority of cases, will not achieve these targets on its own.

CSFOs have communicated advice extensively, building effective working relationships with the farming community. CSF is changing attitudes and behaviour through provision of relevant and trusted advice. Most farmers indicate working with their CSFO increases the priority they give to water pollution. A significant proportion of CSF-engaged farmers indicate they want to do more to reduce water pollution and a significant proportion are considering taking further action.

Holding-specific, one-to-one, advice is most effective for building trust and confidence. However, peer group learning at group events is important for developing farmers' confidence and skills and establishing CSF as a good farming 'norm'.

The 128,691 measures advised through one-to-one farmer engagements have an overall implementation rate of 59.6 per cent. Cost is the most significant barrier to implementation of measures, but capital grants (initially available through CSF and now through Countryside Stewardship) are a strong enabler and driver of action. Repeat advice and farmer understanding of how measures reduce water pollution are also important in terms of implementation.

The majority of implemented measures were judged to be 'mostly effective', with effectiveness linked to farmers' understanding of how measures reduce water pollution.

CSF advice is making a positive contribution to delivery of agri-environment scheme objectives for water. There is strong synergy between the two, pollutant reductions being 4 to 8 times greater on farms implementing CSF advice as well as agri-environment options (compared to farms with agri-environment options only).

Mitigation measures advised through one-to-one CSF advice are estimated to have reduced agricultural losses of nutrients, sediment, and FIOs by between 4 and 12 per cent, on average, across Phase 1 Target Areas.

As a result of reduced pollutant loadings, water quality is estimated to have improved by between 1.2 and 6.5 per cent across water bodies associated with Phase 1 CSF Target Areas (for FIOs, all areas targeted consistently since Phase 1). These improvements contribute towards meeting proportional water quality targets (i.e. based on agriculture's contribution to the pollution issue) within priority Bathing Waters, Natura 2000 Protected Areas, SSSIs and WFD water bodies.

Improvements in mean concentrations of orthophosphate, total phosphorus, *E. coli* and, to a lesser extent, suspended solids were apparent from an analysis of water quality monitoring data. Total oxidised nitrogen and faecal streptococci improvements could not be detected in the water quality monitoring data.

CSF has delivered reductions in pesticide levels across four monitored river catchments. A mean reduction in the proportion of samples exceeding a 0.1µg/l threshold of 34 per cent has been achieved against the backdrop of variable climatic conditions, crop management issues, and overall increases in cropped arable area and pesticide use.

No significant improvement in ecological quality metrics was evident following reductions in agricultural pollutant losses associated with CSF advice delivery. However, the strong association between macro-invertebrate metrics and agricultural pollution pressure indicates that further reductions in pollutant loadings can be expected to lead to ecological improvements over the longer-term.

There is some evidence that trends in groundwater nitrate concentrations have improved within CSF areas, but no clear evidence changes are due to CSF. An advanced statistical modelling approach has now been developed for use in a future assessment of groundwater benefits.

There are indications that CSF is reducing the occurrence of water pollution incidents, relating to agriculture, where advice delivery has been most focused, but incidents are increasing in areas where there are agricultural pressures and less focused CSF delivery.

More broadly, CSF helps maintain a wide variety of natural capital, providing advice that is distinct from that provided by other farm advisers. Benefits particularly associated with CSF include: clean water, biodiversity, provision of animal products and materials, erosion control, reduced flood risk, natural pest control, and beneficial insect pollination.

Evaluation has been, and will continue to be, used to improve the effectiveness of CSF as well as contributing to the wider evidence base for mitigating water pollution from agriculture. Priorities include spatial targeting of geographic areas, prioritisation of farm holdings, and prioritisation of mitigation measures to maximise resulting environmental outcomes. As the policy framework for agriculture evolves, we will look to adapt the evaluation approach developed for CSF in order to provide a more integrated assessment of water policies

Appendix 1

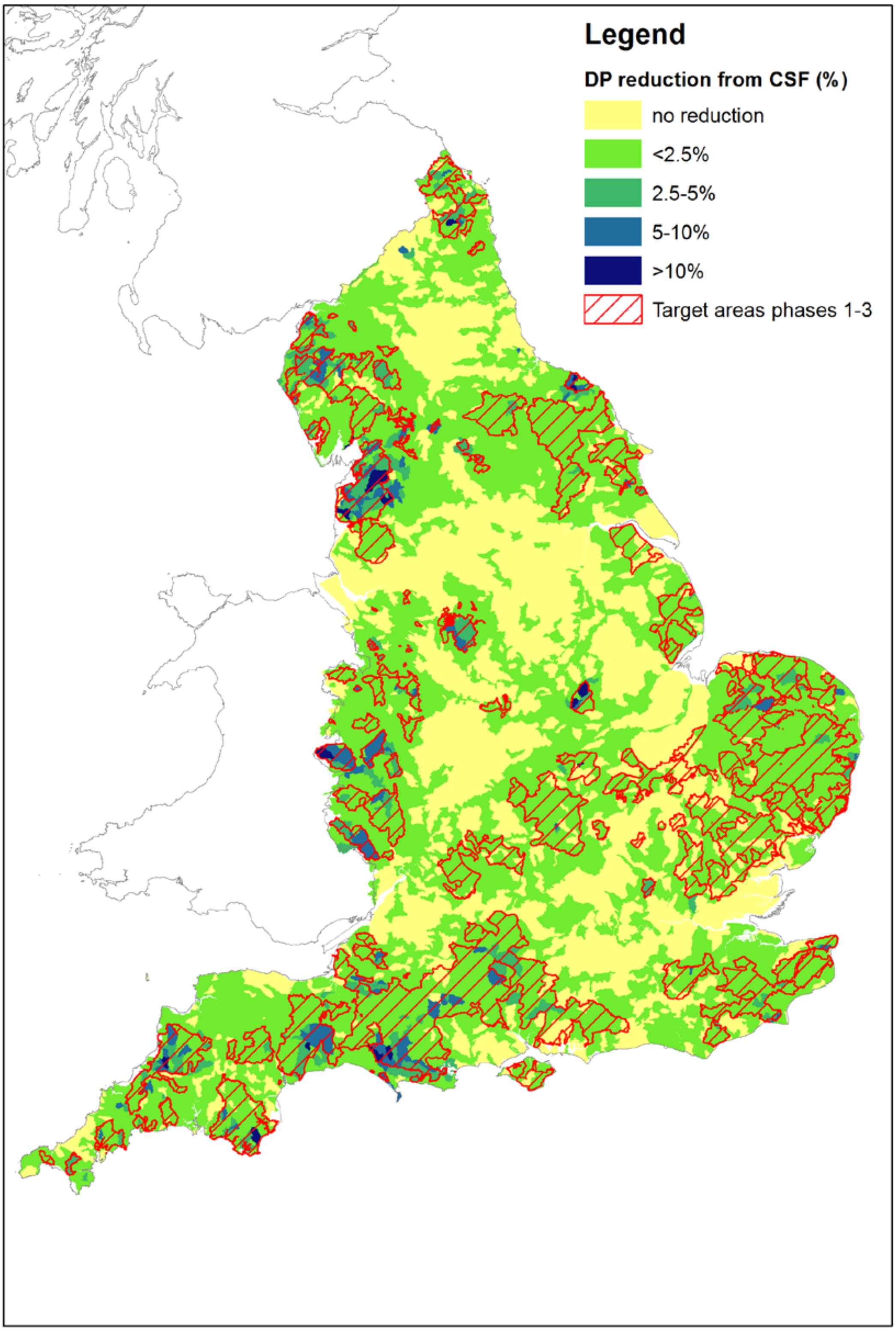
Frequency of different implemented CSF measures and their contribution to estimated reductions in agricultural pollutant losses[25].

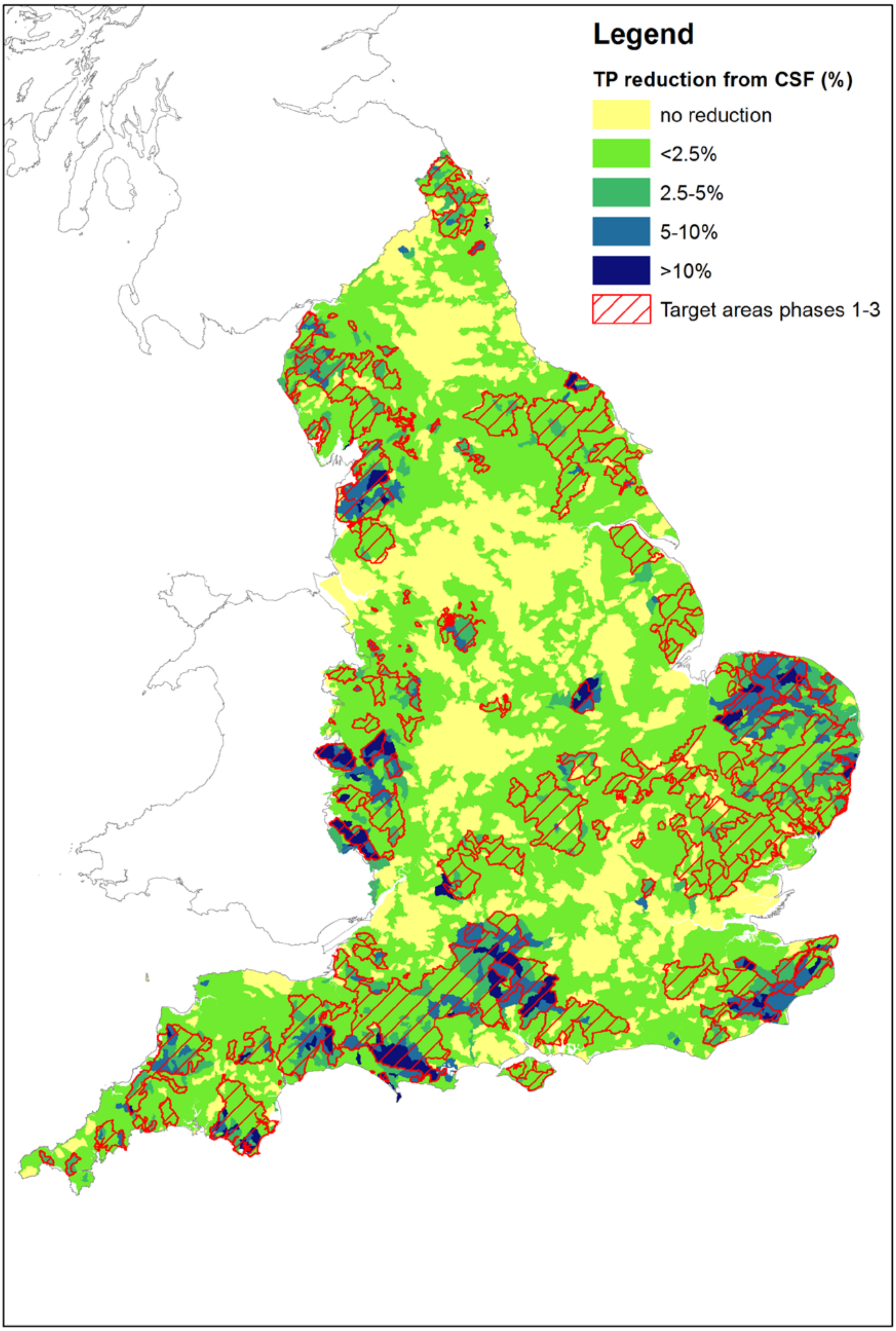
Pollutant / Mitigation measure	Number of measures	% of all CSF measures	% of CSF pollutant reduction
Dissolved phosphorus			
Do not apply P fertiliser to high P index soils	2802	3.9	14.1
Minimise the volume of dirty water produced	7951	11.2	7.2
Do not spread slurry or poultry manure at high-risk times	572	0.8	6.8
Cover solid manure stores with sheeting	2917	4.1	5.7
Install covers on slurry stores	719	1.0	5.7
Total phosphorus			
Establish cover crops in autumn	2662	3.1	15.7
Cultivate compacted tillage soils	3031	3.6	12.0
Cultivate and drill across the slope	2645	3.1	6.5
Do not apply P fertiliser to high P index soils	2802	3.3	5.1
Establish riparian buffer strips	3836	4.5	3.9
Nitrogen			
Establish cover crops in autumn	2662	4.1	30.7
Adopt reduced cultivation systems	790	1.2	7.2
Integrated fertiliser and manure nutrient supply	2742	4.3	5.3
Cover solid manure stores with sheeting	2917	4.5	4.5
Arable reversion to low fertiliser input extensive grazing	289	0.4	4.3
Sediment			
Establish cover crops in autumn	2655	6.2	21.4
Cultivate compacted tillage soils	3020	7.1	16.2
Cultivate and drill across the slope	2638	6.2	8.7
Maintain and enhance soil organic matter levels	1251	2.9	6.4
Establish riparian buffer strips	3836	9.0	5.9
FIOs (*E. coli*)			
Fence off rivers and streams from livestock	3348	6.7	39.4
Reduce field stocking rates when soils are wet	2210	4.4	17.9
Move feeders at regular intervals	1571	3.1	12.5
Construct troughs with a firm but permeable base	650	1.3	9.0
Establish and maintain artificial wetlands	1343	2.7	6.7

[25] Differences in the numbers of some measures across different pollutants are due to a small number of cases where the model version of the farm does not have all the relevant farm sources to associate benefits across all pollutants

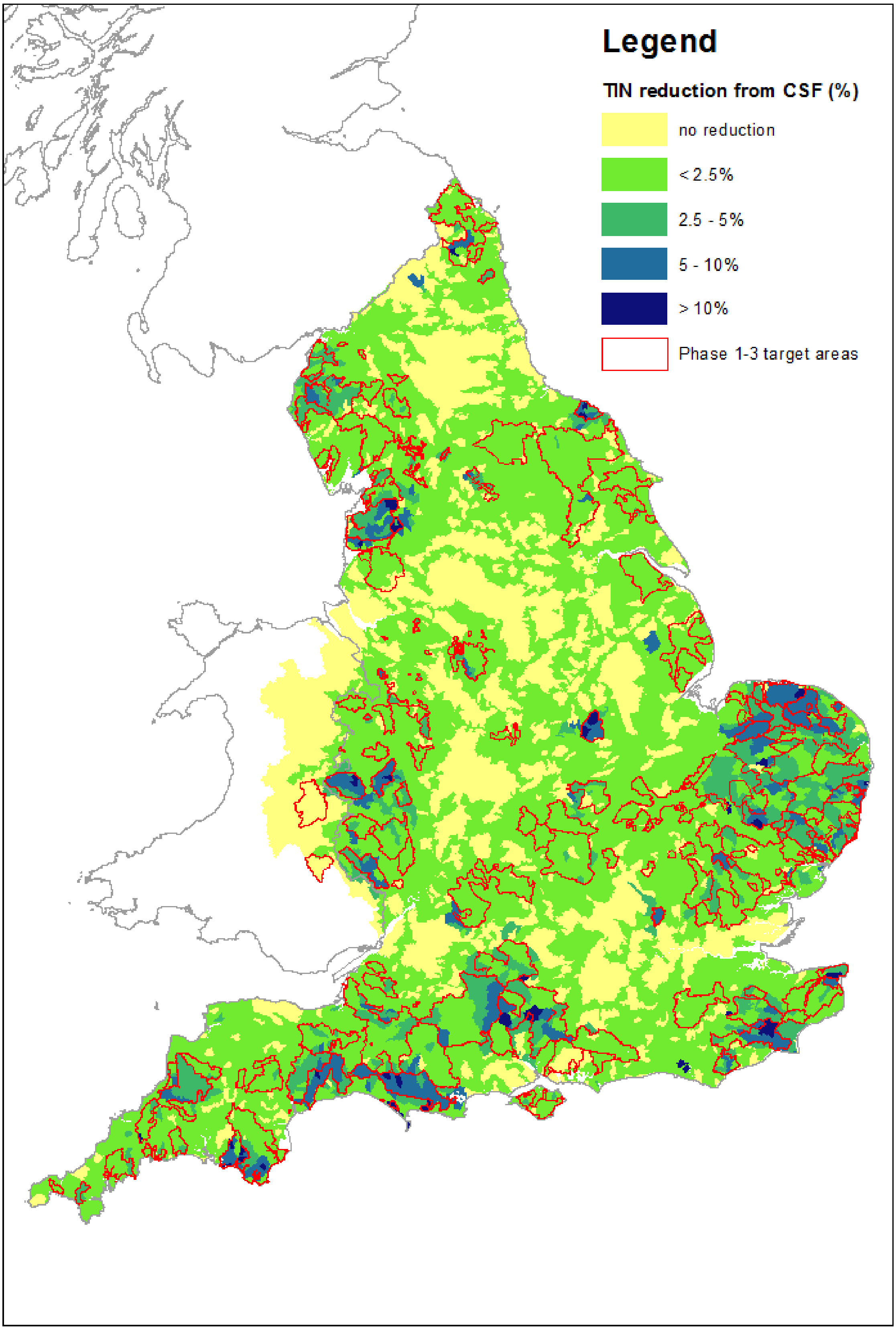
Appendix 2

Modelled water quality improvement (reduced in-river concentration) resulting from CSF advice delivery, for dissolved phosphorus (DP), total phosphorus (TP), total inorganic nitrogen (TIN), suspended solids, and FIOs (*E. coli*).

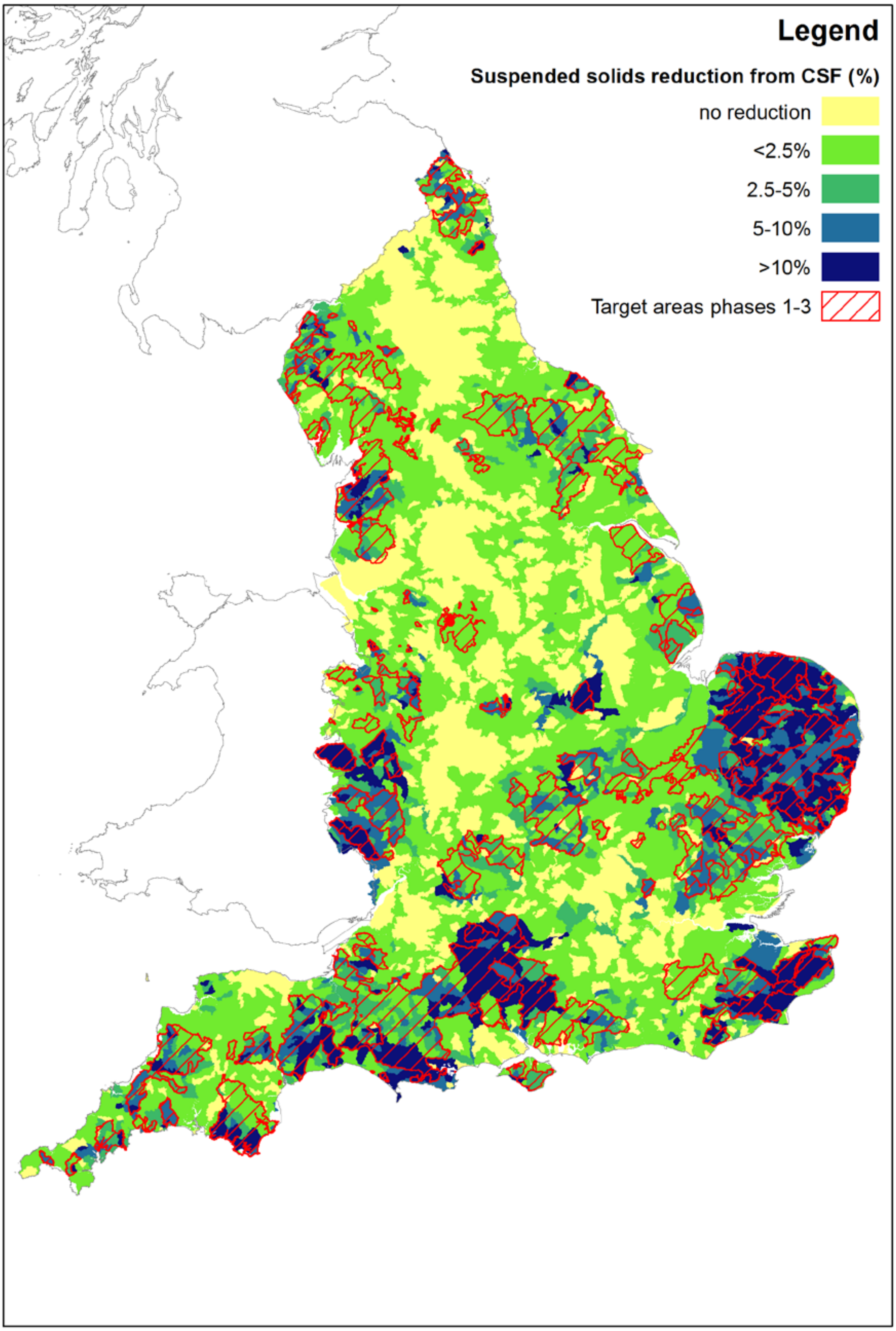


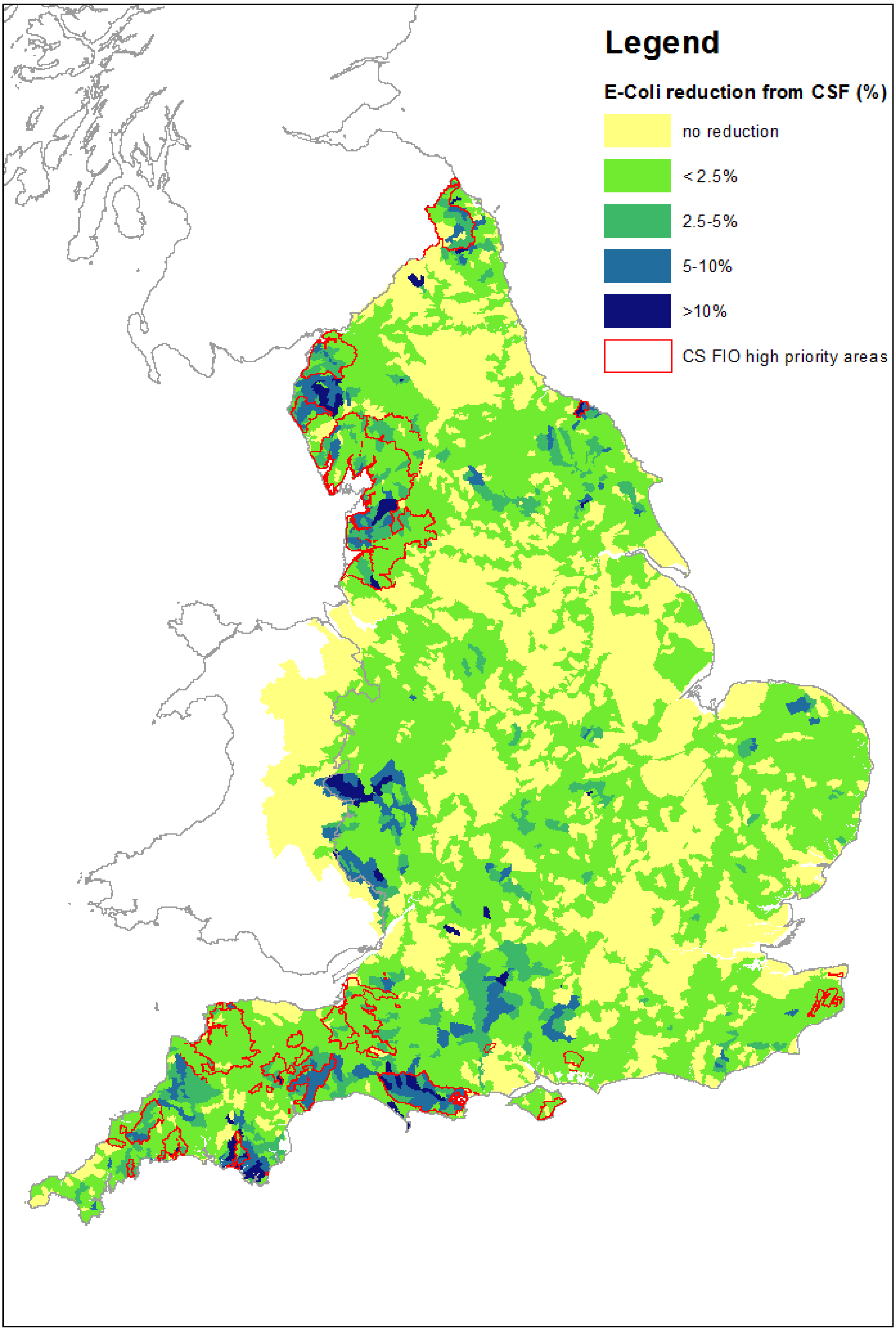


Legend
TP reduction from CSF (%)
no reduction
<2.5%
2.5-5%
5-10%
>10%
Target areas phases 1-3



Legend
TIN reduction from CSF (%)
no reduction
< 2.5%
2.5 - 5%
5 - 10%
> 10%
Phase 1-3 target areas


Legend
Suspended solids reduction from CSF (%)
no reduction
<2.5%
2.5-5%
5-10%
>10%
Target areas phases 1-3


Legend
E-Coli reduction from CSF (%)
no reduction
< 2.5%
2.5-5%
5-10%
>10%
CS FIO high priority areas

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Glossary

AES	Agri-Environment Scheme
ASPT	Average Score Per Taxon
BACI	Before-After-Control-Impact (statistical analysis design)
CCM	Catchment Change Matrix (model)
CGS	Catchment Sensitive Farming Capital Grant Scheme
CS	Countryside Stewardship
CSF	Catchment Sensitive Farming (partnership)
CSFO	Catchment Sensitive Farming Officer
CSMG	Common Standards Monitoring Guidance
CFU	Colony Forming Units
ES	Environmental Stewardship
FIO	Faecal Indicator Organism
IPENS	Improvement Programme for England's Natura 2000 Sites
PPP	Plant Protection Product
PSI	Proportion of Sediment-sensitive macro-Invertebrates
RBD	River Basin District
ROAMEF	Rationale, Objectives, Appraisal, Monitoring, Evaluation, Feedback
SSSI	Site of Special Scientific Interest
TIN	Total Inorganic Nitrogen
TON	Total Oxidised Nitrogen
TDI	Trophic Diatom Index
TP	Total Phosphorus
WFD	EC Water Framework Directive

Front cover image: Working together - Partnership Catchment Sensitive Farming Officer Anne Blokhus and Farmer Guy Brickell on Froghole Farm in the Eastern Rother. © South East Water

Catalogue Code: NE731 ISBN: 978-1-78367-327-8

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