Pembrokeshire Coastal Forum BRICs

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Building Resilience into Catchments – Developing a delivery framework for a Payment for Ecosystem Services (PES) based nutrient trading scheme for the Milford Haven and Cleddau Catchment

Work Package 2 (of 4) Quantification of nutrient reduction through management actions and fit alongside Regulation/Policy

March 2020

ADAS GENERAL NOTES

Project No.: 1020828

Title: Building Resilience in Catchments (BRICS). WP2 (of 4) Quantification of nutrient reduction through management actions and fit alongside Regulation/Policy

Client: Pembrokeshire Coastal Forum

Date: March 2020

Office: **Wolverhampton**

Status: Draft/Final

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EXECUTIVE SUMMARY

Background

The Building Resilience In Catchments (BRICs) project received funding through the Sustainable Management Scheme – Welsh Government Rural Communities – Rural Development Programme 2014-2020, which is funded by the European Agricultural Fund for Rural Development and the Welsh Government. The project is managed jointly by Pembrokeshire Coastal Forum (PCF) and PLANED on behalf of a wider consortium of partner stakeholders who represent the local community from both local and national perspectives.

Building on the work of the Ecosystems Enterprise Partnership – Ecobank (EEP) project[1], the intention of the BRICS project is to employ a payments for ecosystem services (PES) mechanism to develop a nutrient trading / offsetting scheme for the Milford Haven and Cleddau catchment. ADAS in collaboration with EnTrade and the Ecosystems Knowledge Network (EKN) were commissioned by BRICS to develop a Business Development Plan for the nutrient trading scheme. The work to develop the plan is split into four work packages (WP):

1. **Drivers and Structures:** Shows the drivers for nutrient trading in the catchment and describes a proposed structure for a PES-based scheme.
2. **Quantification of nutrient reduction / Management actions / Fit alongside regulation/policy:** Describes how reductions can be quantified and indicates which actions would be suitable for inclusion in the scheme
3. **Implementation Plan / Financing / Considerations for scaling or replicating approach:** Sets out how the scheme will be implemented including inception, monitoring, review, roles/responsibilities, transaction models, and financial case.
4. **Final Report and recommendations:** Pulls together outputs for WP1-3.

This is the report for **WP2**. The specific requirements set out by the BRICS consortium are that WP2 should show:

I. **Scientific basis for assessment of measurements** for nutrient reductions for both landowner conservation management measures and developer site activities requiring offsetting.

II. **Examples of management actions** to reduce nutrients and confidence in measurement of reduction

III. **Assessment of uptake:** Explanation as to why current land management practices to reduce nutrients are undertaken / not undertaken to guide any recommended management actions

IV. **UK / EU legislative frameworks:** Explanation as to how the scheme would fit into existing regulations

[1] https://www.eepecobank.co.uk/reports/

This WP is structured in three sections, focussing on the specific requirements outlined above, with a few minor structural changes to avoid overlap with other WPs. An assessment of uptake of specific management actions will be explored as part of the landowner engagement strategy in WP3. Explanations as to how the scheme would fit into existing regulations was explored at a high level in WP1 and is put into practical context as per the experience of EnTrade as part of WP3. WP4 will explore the fit between the scheme and emerging Welsh policies on agricultural pollution and future land management support.

Section 2 briefly summarises the sources of agricultural nitrate leaching in Milford Haven and Cleddau catchment

Section 3 identifies measures that could be successful for mitigating this nitrate leaching and which would be appropriate for use in the nitrate trading scheme.

Section 4 suggests how the impacts of these measures could be quantified

Section 2: Nitrate leaching in Milford Have and Cleddau catchment

The majority of Pembrokeshire Marine Special Area of Conservation features are in unfavourable conservation status and consequently, nutrient loading into the Milford Haven has been identified as a key issue. The overall objective of this Building Resilience into Catchments project is to design a framework that allows land managers, industry, commerce, government and the third sector to implement a nutrient based Payment for Ecosystem Services (PES) scheme for the Milford Haven and Cleddau catchment. This scheme could then be used for any future development as given the existing nutrient issues it is likely such opportunities would be required to offset any additional nutrient inputs resulting from the development. This part of the project reviews the agricultural management actions that could reduce nutrients and would be suitable for trade by the BRICs trading body and then considers how these reductions could be quantified.

Section 3: Measures to mitigate nitrate leaching

The Farmscoper tool was used to identify those mitigation measures within the Farmscoper library that could potentially have a sizeable impact on diffuse nitrate losses in Pembrokeshire at farm scale. A short-list of candidate measures for use in the Nitrate Trading scheme was then created by removing any measures that were primarily controlled by regulation, had a poor cost-benefit ratio (when only savings in nitrate are considered) or do not lend themselves to a payment scheme for other reasons. The candidate measures were:

- Use slurry injection application techniques
- Establish cover crops in the autumn
- Adopt reduced cultivation systems
- Use nitrification inhibitors
- Undersown spring cereals
- Leave over winter stubbles
- Manure Spreader Calibration
- Construct troughs with concrete base
- Move feeders at regular intervals
- Uncropped cultivated margins
- Use manufactured fertiliser placement technologies.

These measures were estimated to reduce nitrate leaching by at least 0.5 kg ha^{-1} at farm scale for some farm types, with the highest reductions, almost 7 kg ha^{-1}, resulting from improved slurry application techniques. Arable reversion to grassland, reversion to woodland and reduced stocking were then added to the candidate list because - although they are not popular with many farmers - they are potentially the most effective way to reduce nitrate losses, particularly in intensively stocked areas such as Pembrokeshire. For example, losses from dairy farming average over 60 kg ha^{-1}, so even a few hectares of land reverting to more natural conditions could achieve greater impacts than extensive application of the other mitigation measures.

Section 4: Quantification of measure impact

Measures for which it may be possible to determine outcomes using in-field monitoring have been identified. This would provide direct, local evidence for the impacts of those measures for use in the scheme and also, any monitoring data would expand the local evidence base available for use in the calculation of benefits for the scheme as a whole (e.g. providing nitrate leaching rates in the absence of any measures, to which a percentage change could be applied) and for the validation of any models applied. For those measures where monitoring is not appropriate, or sufficient funding is not available, modelling is likely to be the only practical and cost-effective way of quantifying the impacts. The Farmscoper tool, applied in this project, would be one such model capable of determining impacts of the measures. Given the importance of livestock farming in the catchment, and the variation in nitrate leaching with the intensity of livestock farming, it is suggested that a range of impact values be determined which span the variation in management across the catchment, rather than assuming a consistent impact across the whole catchment. The impact value for any specific measure implementation can then be looked up depending upon the management where the measure has been applied.

Next steps

The intention of the BRICS project is to employ a payments for ecosystem services (PES) mechanism to develop a nutrient trading / offsetting scheme within the Milford Haven Waterway and the Pembrokeshire Marine Special Area of Conservation (SAC). This is one of a number of mechanisms that may be utilised to help improve water quality whilst also facilitating economic development in the area.

The Farmscoper tool was used to identify a suite of on-farm nitrate mitigation measures that have relevance for Pembrokeshire whilst also meeting the cost-benefit and regulatory requirements in order to be fit within a trading scheme. Prior to the introduction of these measures on the ground, the level of their associated impact can only be estimated based on modelled outputs and expert advice. The evidence generated from BRICs Workstream one, will help to build the evidence base for implementation and ground truth the acceptability and applicability of the proposed measures.

Building on these recommendations and the proposed structure outlined in WP1, the subsequent WPs will explore the following:

- **WP3 – Implementation Plan** - provides guidance for the Scheme including stakeholder engagement, tools for monitoring and verification of selected interventions, legal contracts and

- **WP4 - Business plan** – provides an explanation of the role the trading body could play in the delivery of public goods and a narrower more detailed exposition of a Nitrate Trading Scheme around the Milford Haven Waterway.

CONTENTS

Tables

Figures

1 INTRODUCTION

The majority of Pembrokeshire's Marine Special Area of Conservation features are in unfavourable conservation status and consequently, nutrient loading into the Milford Haven has been identified as a key issue. There is an intention to prevent any increase in the nutrient loading, so any future development schemes requiring a permit to discharge into the catchment will require some form of offsetting scheme. The objective of this Building Resilience into Catchments project is to design a framework that allows land managers, industry, commerce, government and the third sector to implement a nutrient based Payment for Ecosystem Services (PES) scheme for the Milford Haven and Cleddau catchment. This project consists of three parts: i) a review of different potential offsetting schemes, describing who operates the scheme, how it is managed, costs etc; ii) a review of management actions that could reduce nutrients and how these reductions could be quantified and iii) an implementation plan for the scheme. Including how the scheme will be financially supported in the short and long term. This report is for the second part of the project.

This report briefly summarises the sources of agricultural nitrate leaching in Milford Haven (Section 2), before identifying measures that could be successful for mitigation this nitrate leaching and would be appropriate for use by the BRICs Trading body (Section 3) and suggesting how the impacts of these measures could be quantified (Section 4). Section 5 is a brief conclusion to the report.

2 AGRICULTURE AND NITRATE LEACHING IN PEMBROKESHIRE

Analysis of farm boundary datasets and June Agricultural Survey (JAS) data for land draining into Milford Haven, undertaken by Cascade and ADAS (2015), showed that over two thirds of the agricultural land in this area was used for grazing livestock (Figure 1). Dairying was the main type of grazing on half of this land. Arable cropping (including that found on livestock farms) occupies approximately 10% of the total agricultural area, with wheat and winter barley the main arable crops. There will have been changes in agriculture in Pembrokeshire since these data were analysed, but they are unlikely to significantly alter the overall picture. (Cattle numbers across Wales have changed by only 0.4% between 2010 and 2018.)

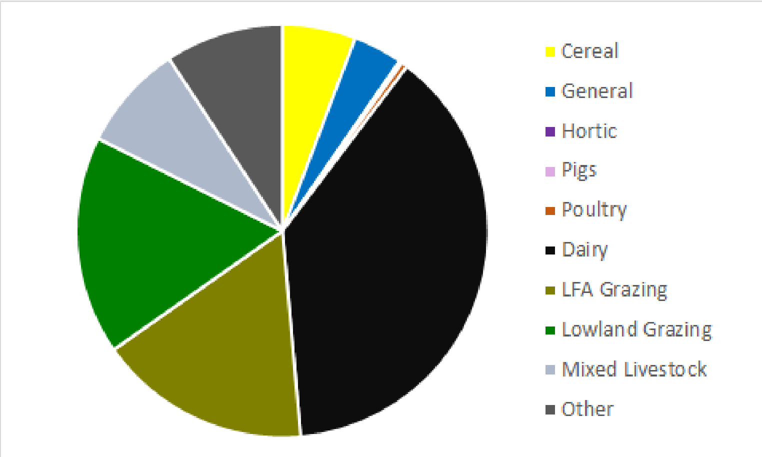

Figure 1 Apportionment of agricultural land for land draining into Milford Haven

As part of the JAS project, the data were inputted into the Farmscoper model (Gooday et al., 2014) to predict annual average pollutant loads. The nitrate leaching 'footprints' on dairy farms was determined to be 66 kg ha^{-1} (Figure 2). This is greater than other farm types (in contrast, nitrate leaching from the less intensively managed cattle and sheep grazing farms was estimated to be 25 kg ha^{-1}). Given the higher average nitrate leaching footprint of dairy farming and the fact that it accounts for over a third of the agricultural land area, dairy farming is estimated to be the source of almost two thirds of the total diffuse agricultural nitrate loss (Figure 3).

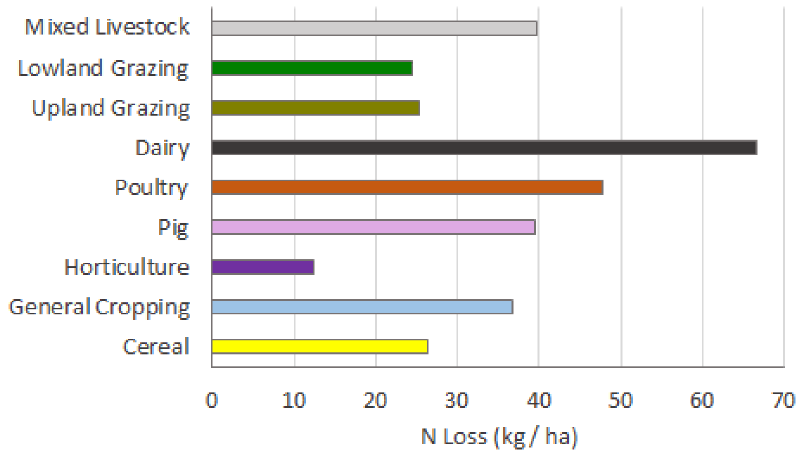

Figure 2 Annual average nitrate leaching losses by farm type for land draining into Milford Haven.

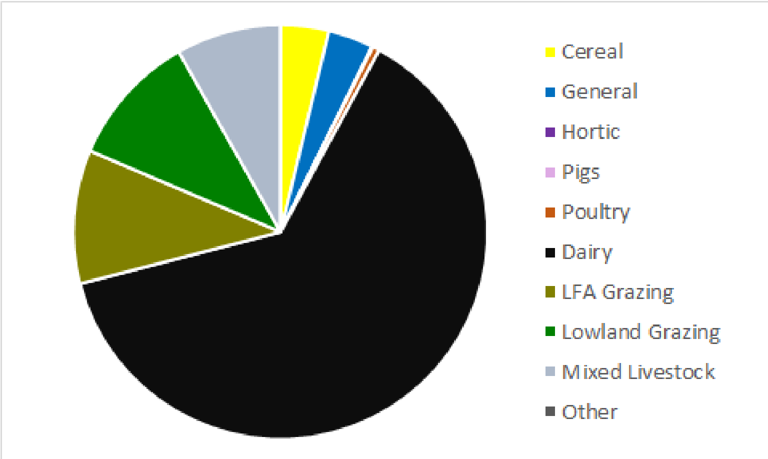

Figure 3 Apportionment by farm type of the total annual average agricultural nitrate leaching load for land draining into Milford Haven.

3 IDENTIFICATION OF KEY MITIGATION MEASURES

The Farmscoper tool was used to identify those measures within the Farmscoper measure library that could have a significant impact on diffuse nitrate losses, estimating their impacts for farms typical of Pembrokeshire. The measure library within Farmscoper consist of about 100 actions that tackle one or more agricultural pollutants, with the list based on the Mitigation Method User Guide (Newell-Price et al., 2011) and certain Environmental Stewardship options.

The tool was applied to a set of farm systems representative of farming in the South-West Wales Water Management Catchment. The impacts of each measure in Farmscoper's mitigation library were calculated at farm scale for these farm systems for a range of soils and climates to identify those measures within the library that could have a significant impact on diffuse nitrate losses. Current implementation of all mitigation measures was set to zero. The impact of the measures was derived by setting the implementation of each, in turn, to 100% (i.e. to all the appropriate area on the farm).

Table 1 shows the modelled maximum farm scale impact calculated for any one farm-soil-climate combination. The measures listed are limited to those with an impact of greater than 0.5 kg ha-1 across a farm. In our opinion, this threshold is appropriate given the effort and costs of scheme administration. The actual impact on any specific farm will vary in different contexts. It will also be dependent upon the proportion of the farm to which the measure is applied. For this reason, a much more detailed version of Table 1 would be needed if modelling was to be used to determine the impacts for use in the scheme. Although this scheme is targeted at nitrate, Table 1 also lists the other pollutants impacted by the measures (out of phosphorus, sediment, nitrous oxide, methane and ammonia).

Given that dairy farming is the main source of nitrate leaching in the catchment, it would be logical to select mitigation measures that have the greatest effect on reducing nitrate leaching arising from dairy farms. However, it is the intensity of management on a dairy farm that is the main cause of the pollution. A reduction in intensity (de-stocking) should, therefore, also be considered as a potential mitigation measure, even though this would generally be considered an unpopular and expensive option. (Care would have to be taken to ensure that it does not simply result in displacement of livestock and pollution to other areas within the catchment.) Farmscoper does not include land use change or reduced stocking in its mitigation library (as these can be represented by changing the inputs to Farmscoper itself) and so these are not listed in Table 1. The reduction in nitrate leaching, and particularly costs, of reversion or reduced stocking would depend heavily on the level of change. Nonetheless, an indication of the reduction achievable can be inferred from the difference in nitrate leaching footprint between dairy farms and other grazing farms in Figure 2.

Many of the management options that attempt to control pollution are either already regulated (e.g. manure applications), have high uptake already (typically associated with potentially cost-saving measures such as use of a fertiliser recommendation system) or are potentially expensive (yard improvement, increased slurry storage and/or increased livestock housing).

The following measures in Table 1 excludes:

- Those that are primarily controlled by regulation.
- Those with a very poor cost-benefit ratio (when only savings in nitrate are considered).

- Those that do not lend themselves to a payment scheme for other reasons.

The measures in Table 1 are unlikely to become regulatory requirements in the near future. The only potential exception is cover crops and winter stubble, which could potentially be included in a future Nitrate Vulnerable Zone (NVZ) action programme or under general rules to reduce agricultural pollution due to the high effectiveness of the measure. Although reversion or reduction in stock numbers may be encouraged or enforced by policy, it will not happen at a scale that would restrict their use in a payment scheme alongside such policy.

Table 1 Farm scale impacts of individual mitigation measures following full implementation. The value shown is the maximum impact achieved on any one of a suite of farm systems designed to reflect the range of farms across Pembrokeshire.

Mitigation Measure	Maximum Farm Scale Reduction (kg NO_3-N ha^{-1})*	Cost-Effect (£ / kg saved)	Assessable by Field Scale Monitoring?	Other Pollutants Impacted (Negatively)	Comment
Use slurry injection application techniques	6.7	10	No	Ammonia	Leaching reductions partly associated with a decrease in fertiliser use, but reduced input costs do not offset contractor costs for slurry injection.
Establish cover crops in the autumn	5.4	3	Yes	Phosphorus Sediment Nitrous Oxide	
Integrate fertiliser and manure nutrient supply	5.2	-29	No	Phosphorus Ammonia Nitrous Oxide	Regulatory, should be cost-saving to farmer due to reduce inputs
Do not spread slurry or poultry manure at high-risk times	2.8	0	No	Phosphorus Nitrous Oxide	Regulatory
Adopt reduced cultivation systems	2.8*	-8	Yes	Phosphorus Sediment	
Use a fertiliser recommendation system	2.7	-3	No	Phosphorus Nitrous Oxide	Regulatory, should be cost-saving to farmer due to reduce inputs
Use nitrification inhibitors	2.2*	1	No	Nitrous Oxide	
Undersown spring cereals	1.9*	-1	Yes	Phosphorus Sediment Nitrous Oxide	
Use clover in place of fertiliser nitrogen	1.6	-53	No	Ammonia Nitrous Oxide	Potential to result in cost-savings to farmer due to reduced inputs, so hard to include in a payment scheme.

Mitigation Measure	Maximum Farm Scale Reduction (kg NO_3-N ha^{-1})*	Cost-Effect (£ / kg saved)	Assessable by Field Scale Monitoring?	Other Pollutants Impacted (Negatively)	Comment
Loosen compacted soil layers in grassland fields	1.4	8	No	Phosphorus Sediment	Increasing infiltration could simply change the pathway by which nitrate is transported rather than actually reducing losses (unlike for phosphorus/sediment, where concentrations are typically lower in sub-surface pathways), and thus the impacts predicted by Farmscoper may be an overestimate. Potential impact of the measure would reduce over time after compaction is removed, and would be dependent upon extent and severity of compaction to start with.
Establish riparian buffer strips	1.1	8	No	Phosphorus Sediment	Impact on nitrate leaching primarily due to taking land out of production
Increase the capacity of farm slurry stores to improve timing of slurry applications	1.1	42	No	Phosphorus (Ammonia)	
Leave over winter stubbles	1.1	12	Yes	Phosphorus Sediment Nitrous Oxide	
Capture of dirty water in a dirty water store	1.0	10	No	Phosphorus	Highly variable impacts depending upon share, usage and connectivity of steading area
Allow grassland field drainage systems to deteriorate	0.9	49	No	(Nitrous Oxide)	
Do not spread FYM to fields at high-risk times	0.9	0	No	Phosphorus Nitrous Oxide	Regulatory
Reduce dietary N and P intakes: Dairy	0.8	31	No	Phosphorus	

Mitigation Measure	Maximum Farm Scale Reduction (kg NO_3-N ha^{-1})*	Cost-Effect (£ / kg saved)	Assessable by Field Scale Monitoring?	Other Pollutants Impacted (Negatively)	Comment
Cultivate compacted tillage soils	0.8	13	Yes	Phosphorus Sediment	See 'Loosen compacted soil layers in grassland fields'
Use dry-cleaning techniques to remove solid waste from yards prior to cleaning	0.7	41	No	Phosphorus Nitrous Oxide	
Manure Spreader Calibration	0.6	1	No	Phosphorus Nitrous Oxide	Will be more effective on arable fields as crops are closer to optimum N rates and so leaching losses are more sensitive to small changes in total fertiliser + manure N applied.
Reduce the length of the grazing day/grazing season	0.5	115	No	Phosphorus Sediment Nitrous Oxide (Ammonia)	
Construct troughs with concrete base	0.5	6	No	Phosphorus Sediment Ammonia Nitrous Oxide	
Move feeders at regular intervals	0.5	17	No	Phosphorus Sediment Ammonia Nitrous Oxide	
Uncropped cultivated margins	0.5	9	No	-	Impact on nitrate leaching primarily due to taking land out of production

Mitigation Measure	Maximum Farm Scale Reduction (kg NO_3-N ha^{-1})*	Cost-Effect (£ / kg saved)	Assessable by Field Scale Monitoring?	Other Pollutants Impacted (Negatively)	Comment
Use manufactured fertiliser placement technologies	0.5	-6	Yes	Ammonia Nitrous Oxide	Reduced fertiliser inputs / increased yields could result in a cost-saving to the farmer, so may not be appropriate to include in a payment scheme. Nitrate leaching could potentially increase if variable rate fertiliser applications result in a net overall increase in fertiliser use.
Reduce field stocking rates when soils are wet	0.5	195	No	Phosphorus Sediment Nitrous Oxide (Ammonia)	

*modelled outputs from Farmscoper are lower than measurements made in-field by EnTrade. The measured outputs of these interventions are reflected in costings for WP4

A short-list of measures appropriate for a payment scheme was then created. This list also includes an estimate of the current uptake of these measures, and an estimate of willingness for farmers to implement them as part of the nutrient trading scheme (although this would depend on the payment rates available for each measure). Table 2 includes both the use of cover crops and the retention of winter stubbles; two measures which are mutually exclusive. Cover crops should be more effective at reducing nitrate loss than retaining stubbles. Nonetheless, it would be appropriate to retain both measures in the list as there are agronomic reasons why farmers would prefer to implement one option over the other.

These measures are unlikely to become regulatory requirements in the near future. The only potential exception is cover crops and winter stubble, which could potentially be included in a future Nitrate Vulnerable Zone (NVZ) action programme or under general rules to reduce agricultural pollution due to the high effectiveness of the measure. Although reversion or reduction in stock numbers may be encouraged or enforced by policy, it will not happen at a scale that would restrict their use in a payment scheme alongside such policy.

Table 2 Measures appropriate for use in the nutrient trading scheme

Mitigation Measure	Current Uptake	Likely Trading Scheme Uptake
Arable reversion to low/zero input grassland	-	Medium
Reversion to woodland	-	Low
Reduced stocking on grassland	-	Low
Use slurry injection application techniques	Low	Low
Establish cover crops in the autumn	Low	High
Adopt reduced cultivation systems	Low	Medium
Use nitrification inhibitors	Low	Low
Undersown spring cereals	Low	Medium
Leave over winter stubbles	Medium	High
Manure Spreader Calibration	Medium	High
Construct troughs with concrete base	Low	Medium
Move feeders at regular intervals	High	Low
Uncropped cultivated margins	Low	Medium
Use manufactured fertiliser placement technologies	Low	Med

The measures proposed do not have significant barriers to uptake which would stop them being used, provided that payment rates are sufficient (e.g. reversion payments per ha are equivalent to gross margins) and advice is provided as to the cost, benefits and methodology for implementing such measures (e.g. weed issues associated with reduced cultivation). The major exception to this would be reversion to woodland (and to a lesser extent reversion to grassland). In this case, there would be constraints on returning land use to its pre measure implementation state. For the same reason, these options may also be less appropriate for tenant farmers.

The following sections briefly describe the method of implementation and associated costs for each measure. The information is from the Farmscoper library or, for those measures not included, from the Mitigation Method User Guide (Newell-Price et al., 2011).

3.1 Arable reversion to low/zero input grassland

If land is unfertilised and un-grazed, land could be left to regenerate following harvest with no cultivation, no grass seeding and regrowth topped one year in five. No sale of machinery would be involved.

Assuming the land is grazed, then costs would depend upon:

i) whether there are already livestock on the farm,

ii) whether the grazing land could be rented out to another enterprise,

iii) costs of new infrastructure and machinery, changes in gross margins and changes in staff and/or training.

3.2 Reversion to woodland

The measure would involve a loss of income from arable farming or grazing livestock for the reverted land. Income would depend upon the use of woodland. Assuming woodland is used for timber, then most of the value would be realised when the woodland is clear felled (which may not happen for over 50 years).

3.3 Reduced stocking on grassland

Costs would depend upon whether the reduced stocking rate was achieved through:

i) a less-intensive version of the same system across the whole farm,

ii) a reduction in the herd size, with some marginal grassland removed from management,

iii) by switching system for the whole – e.g. converting from dairying to beef.

3.4 Use slurry injection application techniques

Slurry is delivered to the soil in shallow surface slots (5-10 cm depth, at 20-25 cm spacing) which are cut by preceding discs, or much deeper into the soil (c. 25 cm depth) where slurry placement is behind a tine. Injection is assumed to take longer due to either a lower tractor speed or a narrower application width and thus greater distance travelled. Costs do not take into account changes in the spreading window or small improvements in crop N recovery, or the need to purchase any new machinery.

3.5 Establish cover crops in the autumn

If land would be 'bare' over-winter, a cover crop is established immediately post-harvest or, at the latest, by mid-September. In order to protect the soil surface throughout the period when surface runoff could occur, the cover crop is not destroyed until the land is due to be prepared for the next crop. The cost of a cover crop depends on how it is established, seed costs, destruction methods and the potential for yield benefits and reduced fertiliser use in subsequent crops, which can potentially result in a saving to the farmer. Our estimated cost is £60 ha-1, which is a mid-range estimate based on the requirements for light harrowing, broadcasting seed and rolling of the seedbed, with no yield or fertiliser changes.

3.6 Adopt reduced cultivation systems

Switch from a plough-based system to using reduced cultivations, using discs or tines, to cultivate the soil surface as the primary cultivation in seedbed preparation (typically 10-15 cm cultivation depth). There may be the need for additional weed control.

3.7 Use nitrification inhibitors

Addition of nitrification inhibitors (NIs) to applied manufactured N fertilisers and organic manure. NIs are relatively expensive, but reductions in manufactured fertiliser N requirements (through reduced N losses) may partially offset this cost.

3.8 Undersown spring cereals

Spring cereal crops are established and undersown with a grass ley. The undersown grass ley is retained until summer of the following year. It is assumed that both spring cereals and ley grass are part of the normal cropping rotation, but undersowing requires less seed bed preparation than usual before sowing the grass seed. The reduction in costs associated with seed bed preparation may be greater than any costs associated with a reduction in yield of the spring cereal crop, so this measure may result in a cost-saving to the farmer.

3.9 Leave over winter stubbles

Cultivations are delayed until spring time. Other demands on time in the spring mean these operations may now need to be performed by a contractor resulting in additional costs. A lack of frost action means additional cultivation is required.

3.10 Manure Spreader Calibration

Determine the actual rate and evenness of manure (slurry and solid manure) applied by a spreader, and adjust it to obtain the desired agronomic rate. Calibration is assumed to be undertaken by a contractor.

3.11 Construct troughs with concrete base

Construct water troughs with a firm base to reduce poaching damage to the soil. Costs are based on purchase of a new water trough and construction of a permeable base. It is assumed water is brought by bowser to the trough as previously. This means that there is no change to the cost of water supply.

3.12 Move feeders at regular intervals

Feed troughs, feeding racks and other feeding devices for outdoor stock are re-positioned at regular (at least monthly) intervals to reduce localised areas of 'severe' poaching damage and nutrient accumulation. It is assumed that the fields already have suitable feeders that can be towed by a tractor.

3.13 Uncropped cultivated margins

An uncropped margin is cultivated in autumn or spring, with no fertilisers or manures are applied and herbicides only applied to control injurious weeds (spot treatment) and pernicious weeds that have set seed. The margin would be destroyed as part of normal cultivation in the following year. Loss of arable production is partly offset by reduced management and inputs.

3.14 Use manufactured fertiliser placement technologies

Install GPS and monitoring equipment along with licence for the local network, to allow variable rate fertiliser applications. The potential impacts of precision farming could be small as, although it should increase yields, it may not change overall fertiliser rates, and on grassland fields, fertiliser rates are nearly always below the breakpoint in the relationship between input and loss.

4 ESTIMATION OF MEASURE IMPACTS ON NITRATE LEACHING

Determining the impacts of the measures on nitrate leaching would be possible via one of the following approaches, which are discussed below.

1. Monitoring
2. Modelling
3. Scientific literature evidence / expert judgement

The approaches are listed in order of preference, with monitoring the preferred approach as it could most accurately reflect local environmental conditions and farming practices. For each mitigation measure, a look up table of impact values would be created. The look up table would capture any variation in impact due to different environmental conditions and farming practices – for example, for grassland measures, it would be essential for impacts to account for management (e.g. stock density, fertiliser use / manure management, grazing/cutting regime) to reflect its importance on nitrate leaching. Where there is no variation in impact, or evidence to determine what the variation is, then the measure may have a single impact value in the lookup table. Monitoring may only be able to inform some parts of the look up table (due to the costs of monitoring) and it would be necessary to extrapolate or gap fill the other parts with modelling or expert judgement.

4.1 Monitoring-based estimates

Monitoring would be the best way to obtain data on the impacts of the measures which would reflect local environmental conditions and farming practices. The most feasible way of monitoring the impacts of the measures is through the measurement of soil mineral nitrogen (SMN) in autumn or over-winter leaching (using porous pots). The data could provide an evidence base for losses with and without the measures in place, from which impacts can be determined.

Due to the poor relationship between leaching and SMN for grassland fields, only the porous pot approach would be viable for grassland measures. Monitoring would only be appropriate to 'field management' options (such as cover cropping) and not those targeting steading issues or more temporally variable pollutant sources (e.g. reducing field stocking rates when soils are wet) – appropriate measures for monitoring are listed in Table 1.

An additional benefit of any monitoring data collected would be that it could be used to validate any models used for assessing the impacts of measures, hopefully demonstrating the appropriateness of the model when applied to local conditions.

4.2 Model-based estimates

Model-based impacts can be determined for all measures through the Farmscoper tool. For certain measures, it may be more appropriate to use a tool designed specifically to estimate the impacts of such changes in management. The only example of this for the measures in Table 2 would be the use of the MANNER tool (Chambers et al., 1999, Nicholson et al., 2015) to estimate the impacts of changes in slurry spreading technique.

The approaches could be used to create a lookup table of impacts for the different options. It may be appropriate for impacts to account for changes in physical environment. For grassland systems, it would be essential for impacts to account for management (e.g. stock density, fertiliser use / manure management, grazing/cutting regime) to reflect the importance of these factors on nitrate leaching.

4.3 Expert Judgement

For some measures, there may be insufficient evidence to parameterise a model-based assessment, or the target of the mitigation activity might be outside of scope of the model (for example, Farmscoper does not consider losses from silage). In these cases, it may be necessary to determine the impacts according to evidence available in published scientific literature or, failing that, based upon expert judgement. However, the current list of measures has been derived from the Farmscoper model, so there should be no need to resort to expert judgment unless additional measures are considered.

5 CONCLUSIONS

There is a need to identify appropriate mitigation measures for use in a nitrate trading scheme based around Milford Haven, and describe how the benefits of those measures could be ascertained.

This report describes how a prioritised set of measures that could be implemented on farms in the Milford Haven Catchment as part of such a scheme have been identified. Using the Farmscoper tool, the maximum likely farm-scale impact of full implementation of each measure has been determined, which ranges from 0.5 kg ha-1 of nitrate (decided as a minimum threshold for impact) to almost 7 kg ha-1. Arable reversion and reduced stocking rates have also been included in the set of measures as, although unpopular, they are potentially far more effective than the other measures. Measures that are primarily controlled by regulation or with a very poor cost-benefit ratio have been excluded even if they are effective at reducing nitrate leaching as they would not meet the requirements for trade.

The Farmscoper tool could be used to quantify the impact benefits ascribed to these measures when implemented within the scheme. As the impacts vary with environmental and farm management conditions, it would be appropriate to create a suite of impact values from which the relevant value could be taken given the management of the farm. However, for a few mitigation measures, it would be possible to monitor the impacts in the field, either using porous pots to monitor concentrations in soil drainage or sampling soil mineral nitrogen in the autumn and spring. Such monitored data would provide a more robust local evidence base for ascribing impact benefits from measures and would also provide data that could be useful for validation of models applied and model-based impact assessments.