Natural England Commissioned Report NECR291

Root Cause Analysis for the North Devon Landscape Pioneer

First published 21st May 2020

www.gov.uk/natural-england

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

The 25 Year Environment Plan (HM Government, 2018) aims to improve the state of the environment within one generation. The North Devon Landscape Pioneer was one of four pioneers tasked with testing and trialling new approaches set out within the 25 YEP.

This report forms part of the natural capital process trialled by the landscape pioneer. The aim of this process was to create a strategy for North Devon which enabled environmental, institutional and financial innovation by using natural capital and participatory approaches.

This report uses an innovative approach to present the multiple causes of environmental problems in North Devon using a visual method.

Root Cause Analysis maps demonstrate the causes of problems and the links between them. Individual causes are shown within a strategic picture of the system leading to the problem.

The root cause maps allow the pinpointing of interventions which treat the priority problems strategically.

The maps were created by the project team and partners in North Devon. The project team would like to thank those involved for their input which was essential to be able to produce this report.

The evidence and interventions within this report are discussed in the Natural England Research Report Number 083 – A Natural Capital Strategy for North Devon – along with the whole natural capital process trialled by the landscape pioneer.

This report should be cited as:

Eftec (2020). Root cause analysis for the North Devon Landscape Pioneer. Natural England Commissioned Report Number 291.

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Keywords – Root cause analysis, natural capital, ecosystem services

Further information
This report can be downloaded from the Natural England Access to Evidence Catalogue: **http://publications.naturalengland.org.uk/** . For information on Natural England publications contact the Natural England Enquiry Service on 0300 060 3900 or e-mail **enquiries@naturalengland.org.uk**.

ISBN 978-1-78354-641-1

eftec

Root Cause Analysis of problems affecting ecosystem services in the Landscape Pioneer (North Devon)

Final Report

For Natural England

Report submitted to Natural England May 2018

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Acknowledgements

The project team would like to thank Tim Sunderland (Natural England), Alice Lord (Natural England), Patricia Rice (Natural England) and Jo Traill-Thomson (Natural England) for steering the work and Andy Bell (Devon CC / FC / North Devon Biosphere Reserve / Devon LNP), Lisa Schneidau (Devon Wildlife Trust / North Devon NIA / Devon LNP), Brett Grosvenor (Environment Agency), Jenny Carey-Wood (North Devon Coast AONB), Mark Prior (Forestry Commission), Jeremy Sabel (Natural England), David Smith (SW Water), Paul Cottington (NFU), Russell Smith (Westcountry Rivers Trust), Ross Cherrington (Westcountry Rivers Trust), Laura Francis (Natural England), Rebecca Aston (Natural England), Richard Smith (Environment Agency), Chrissie Ingle (Devon CC), Andrew Jones (North Devon DC), Andrew Austen (North Devon DC), Rob Large (Natural England), Christine Goodall (Natural England), Sarah Jennings (Devon CC), Peter Chamberlain (Devon CC), Andrew Butler (NFU), Patricia Rice (Natural England), Aisling Lannin (MMO) and Cheryl Willis (Natural England) for their work in identifying and analysing the causes and for suggesting potential interventions. Apologies for any omissions from this list.

CONTENTS

Summary

Natural England is working with local stakeholders to undertake a root cause analysis of problems affecting ecosystems and their services in the North Devon Landscape Pioneer area, and to identify and appraise potential interventions to address these problems.

Work with local partners identified eight environmental problems or potential problems affecting ecosystems and their services in North Devon, for which action is a priority:

- Permanent grassland and water quality;
- Improved pasture and water quality;
- Improved pasture and climate regulation;
- Arable farmland and water quality;
- Culm grassland and water regulation/ other ecosystem services;
- Coastal margins, tourism, recreation and cultural services;
- Woodland and climate regulation; and
- Deciduous woodland and water regulation.

This report sets out:

- A Root Cause Analysis map for each of the priority problems, each supported by a narrative and summary of best available evidence;
- A list of possible interventions to address these problems; and
- An initial assessment of the interventions proposed, using an agreed set of criteria, and outlining the likely nature and balance of the benefits and costs of the interventions.

Root Cause Analysis (RCA) has previously been applied in addressing a range of problems in different fields, such as process engineering, health and safety and quality management, but there are few examples in the literature of its application to environmental problems, at least in the way described in this report. The examples demonstrate that RCA can readily be used to examine the causes and pathways of problems affecting the natural environment.

The RCA approach helps to identify and assess the range of potential interventions that can be applied to address natural environment problems, locating them at different stages in the chain of causes and effects. It therefore helps to highlight those types of intervention which address the root causes of the problems identified, and those that deal with the symptoms and environmental effects.

The exercise has helped to highlight a small number of potential interventions that would represent a significant change to current actions taken to improve the natural environment. It is hoped that the RCA provides a helpful conceptual framework which can be used to inform further analysis of potential interventions to address the ecosystem problems assessed.

Future work could:

- Further refine the evidence base for each RCA;
- Prioritise the potential interventions identified, building on the analysis above to select a smaller number of interventions to be specified, developed and assessed in greater detail;
- Specify the most promising interventions further, setting out the scale and nature of action required, the actors involved, resources required, timetable and measures of success; and
- Further analyse and quantify the likely costs and benefits of each priority intervention.

1. Introduction

1.1. Background

Natural England is working with local stakeholders to undertake a Root Cause Analysis of problems affecting ecosystems and their services in the North Devon Landscape Pioneer area.

Work with local partners identified eight land uses which give rise to problems or potential problems for the delivery of ecosystem services, and for which action is a priority (Table 1).

Table 1: Priority problem areas to be investigated

Ecosystem / land use	Ecosystem services
Improved pasture	Water quality (water purification)
Arable farmland	Water quality (water purification)
Culm grassland	Water regulation
Coastal margins	Tourism, recreation and cultural services
Woodland	Climate regulation
Deciduous woodland	Water regulation
Improved pasture	Climate regulation
Permanent grassland	Water quality (water purification)

The objectives of the project were to:

1. Complete a Root Cause Analysis map for each of the priority problems above, supporting each map with the best available evidence and suggesting potential interventions;
2. Assess the most strategic interventions for their potential impact on multiple ecosystem services, biodiversity and the resilience of the ecosystem; and
3. Assess the likely economic case for each strategic intervention, examining the likely costs and benefits and those affected by each.

1.2. Introduction to Root Cause Analysis

Root Cause Analysis (RCA) is a collection of problem solving methods used to identify the real cause of a problem. It seeks to identify the point in the causal chain where an intervention would prevent the problem from occurring – this enables preventive action to be taken, rather than focusing efforts on dealing with the symptoms of the problem[1]. It is hoped that understanding the root causes of problems affecting ecosystems and their services in North Devon should help to point to more effective interventions.

[1] https://quality-one.com/rca/

RCA has been applied in a range of different fields (e.g. civil aviation, quality management, health and safety, process engineering)[2]. However, it has rarely, if at all, been applied to the assessment of problems in the natural environment.

A common approach to RCA is to apply the "5 whys" approach to assessment of the causes of a problem (Figure 1). This involves identifying one or more immediate causes of the problem, and asking why they occur. The analyst then examines why each of these causes occurs. By asking "why" around five times, the chain of causes for each problem can be mapped out and the root cause can usually be identified.

This "5 whys" approach has been applied to the eight problems listed above, drawing on the expertise of local Pioneer partners and evidence in the literature.

1.3. Methodology

The work involved:

- A review of literature and evidence for each problem, drawing on national and local evidence;
- A series of teleconferences with Pioneer partners with knowledge of each issue in North Devon. 8 teleconferences were held, one for each problem;
- The drafting of an RCA map for each problem, applying the "5 whys" approach;
- A workshop, involving Pioneer partners, held in Exeter on 20 February 2018, to discuss and refine these maps, and to begin to identify interventions to address each problem;
- Further analysis of the RCAs and development of evidence-based narratives to support each one;
- A second series of teleconferences to define interventions for each problem;
- Analysis of the proposed interventions against a defined set of criteria, and examining in qualitative terms their costs and benefits;
- The preparation of this report, finalising the RCA maps, evidence-based narratives, and analysis of potential interventions.

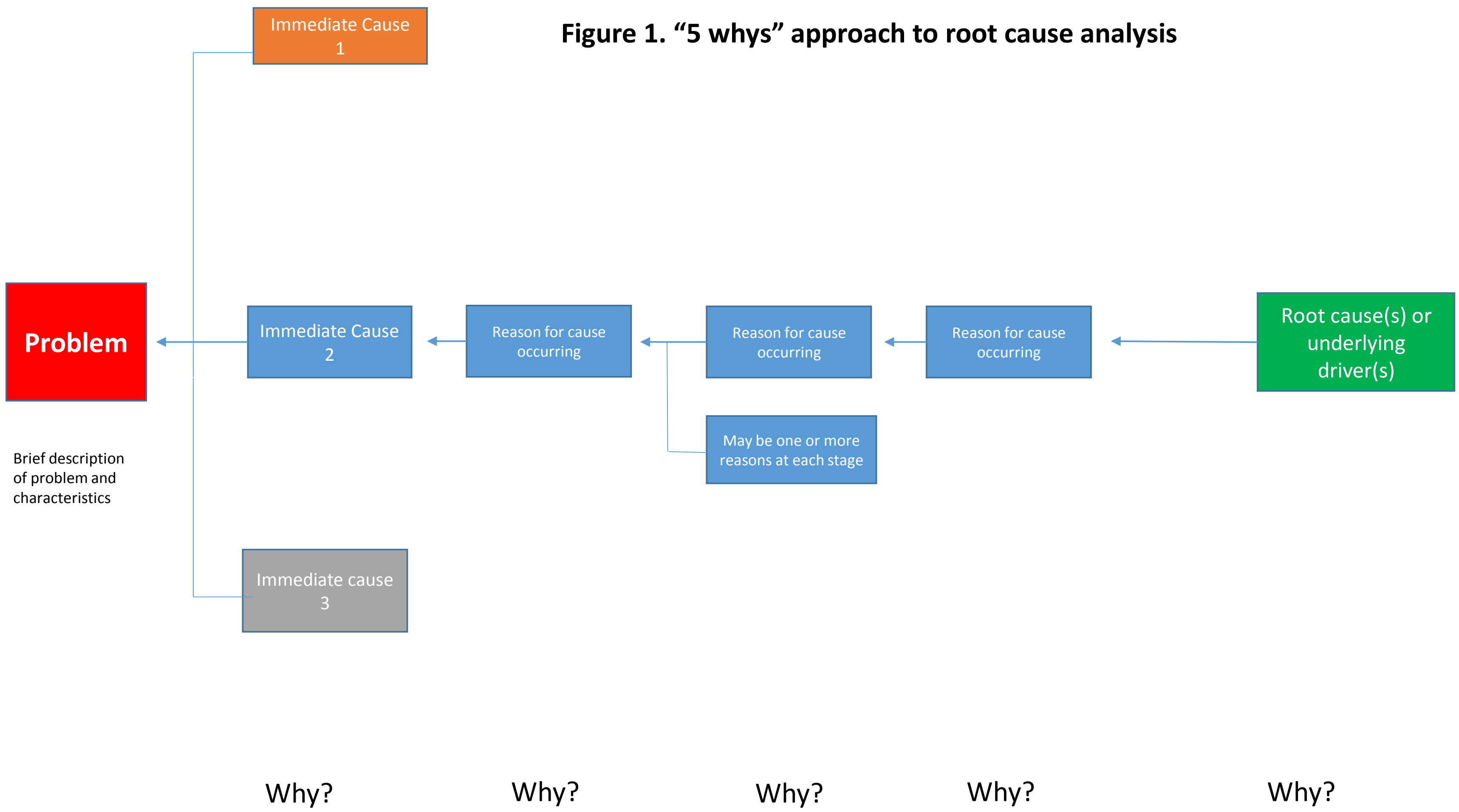
1.4. This report

This report presents the results of the Root Cause Analysis work. It is structured as follows:

- Sections 2-9 present the Root Cause Analysis maps, supporting narratives and evidence, and suggested interventions, for each of the eight problems;
- Section 10 analyses the interventions proposed by partners; and
- Section 11 presents overall conclusions from the exercise.

[2] Examples of sources include https://www.thinkreliability.com , https://quality-one.com , https://www.mindtools.com http://asq.org/

Figure 1. "5 whys" approach to root cause analysis



2. Permanent Grassland and Water Quality

2.1. Permanent Grassland, Water Quality and Ecosystem Services

North Devon supports ecologically important rivers, estuaries and bathing waters. The Taw and Torridge are the main rivers flowing through the Biosphere Reserve, with many smaller tributaries feeding into them before they reach the estuary mouth and sea (NDBR, 2014). Achieving good water quality is important for wildlife and people; the quality of coastal waters in particular is important in maintaining cultural services for residents and visitors, and supporting the tourism industry (NDBR, 2014). Poor river water quality is implicated in the decline of species such as the kingfisher and freshwater pearl mussel (NDBR, 2014).

The UK National Ecosystem Assessment stressed that lower intensity management of semi-natural grassland is critical in maintaining water quality and quantity, while many of the UK's water quality problems have resulted from diffuse pollution caused by agricultural intensification (UKNEA, 2011). Permanent grassland[3] is a major land use in North Devon, estimated to amount to 58,000 hectares (eftec, unpublished), and its management strongly influences the quality of water in the area.

2.2. The Problem

Farming is a major contributor to water pollution nationally, and is estimated to account for approximately 60 per cent of the nitrates, 25 per cent of the phosphorus and 70 per cent of the sediments entering our waters (Natural England, 2011; POST, 2014b). Diffuse pollution from agriculture and rural land use is directly attributed to 28% of failures to meet Water Framework Directive standards (POST, 2014b).

The Environment Agency's Catchment Data Explorer indicates that in 2016, only 3 out of 42 water bodies in the Torridge catchment were in good ecological status, with 32 classed as moderate and 7 as poor. Agriculture contributed to 22 out of 87 reasons for not achieving good status, being the second largest cause behind the water industry (with discharges from sewage treatment plant being the most frequent pressure). A similar picture applies to the Taw catchment and North Devon streams. Diffuse pollution, involving nutrients, sediment and phosphate, is the primary pressure in the agriculture sector, although agricultural point sources were implicated in two failures in the Taw catchment. Most reasons for failures in the agriculture sector are identified as being caused by livestock, with poor management of nutrients and soil also identified in a small number of cases. Problem pollutants include phosphates, nitrates, faecal indicator organisms, sediment and pesticides (Natural England, Defra and Environment Agency, 2016).

2.3. The Causes

Water quality issues result from pollutant run-off and soil loss from agricultural land (UKNEA, 2011; Natural England, 2011; POST, 2014b). This is often associated with high rainfall and is often exacerbated by:

- **High levels of application to land of slurry and fertilisers.** Excess nitrogen compounds from fertilisers and manures may be released as nitrate leaching to ground and surface waters (UKNEA, 2011). Phosphorus from fertilisers tends to bind with soil particles, so sediment loss is associated with elevated phosphorus concentrations in waters and accounts for around 29% of phosphates in rivers in the UK (UKNEA, 2011). High levels of slurry production are caused by high stocking rates, especially in dairy systems, and may exceed

[3] Permanent grassland is land used to grow grasses that has not been included in the crop rotation of the holding for five years or longer. It includes grasses grown naturally (self-seeded) or through cultivation (sown) (Natural England, 2014).

the carrying capacity of the land. Inadequate slurry storage may exacerbate the problem, by reducing flexibility in the timing of slurry applications. The timing of slurry application, and the application method can also significantly affect the amount of runoff from fields (POST, 2014b). The active monitoring of soil nutrient and moisture levels allows the precise application of fertilisers and nutrients as they are needed (POST, 2014b).

- **Soils affected by compaction and erosion.** Run-off and soil loss are increased if soils are left bare or are compacted, particularly at times of high rainfall (Defra, 2005; Cranfield University, 2015). Soils may be compacted by use of machinery, particularly in the winter months. They may be compacted or poached through pressure from livestock, including winter grazing by sheep. Livestock management factors such as intensity (number of animals per hectare) and duration on land also contribute to erosion risk (Cranfield University, 2015). Pressures are influenced by the timings and methods of operations and grazing regimes, particularly in the winter months. Rainfall (intensity and amount) determines the generation of surface runoff, commonly as saturated overland flow or less frequently where rainfall intensity is in excess of infiltration rate (especially for soils prone to surface capping and crusting; Cranfield University, 2015). Managing farm traffic to minimise soil compaction can help to improve soil health and water absorption (POST, 2014)b. The layout of the farm and its infrastructure is also a factor – for example the location of gates, tracks, feeding and watering points may contribute to pressure points where erosion and compaction are caused. Wetter winters predicted by climate change scenarios will increase the risk of compaction as soils remain wetter for longer periods (Cranfield University, 2015).

- **Direct contact between livestock and watercourses.** Where livestock are allowed to access watercourses, this can contribute to water quality problems through manuring and bankside erosion (Environment Agency, undated). Erosion can also result from grazing very close to watercourses. These problems can be prevented by fencing off watercourses, ensuring that fences are positioned an appropriate distance from the bank, and, where necessary, providing alternative watering points. Preventing livestock access to streams and rivers reduces direct sediment inputs and allows the development of riparian zones alongside streams, providing a long-term pollution reduction benefit (POST, 2014b), as well as other ecosystem service and wildlife benefits.

- **Pollutant run off slurry stores and farmyards.** Leaking slurry stores are a significant source of nitrogen and phosphates, and uncovered stores can overflow in heavy rain (POST, 2014b). Pollution enters watercourses as a result of run-off from slurry stores and farmyards at times of rainfall. This may be exacerbated by inadequate capacity for slurry storage and may be affected by other aspects of farm infrastructure, layout and management. Separation of clean and dirty water helps to control slurry volumes and management.

Socio-economic factors are among the root causes of soil erosion and water pollution, encouraging the intensification of production and uses and management of land described above (Boardman, 2013; Cranfield University, 2015).

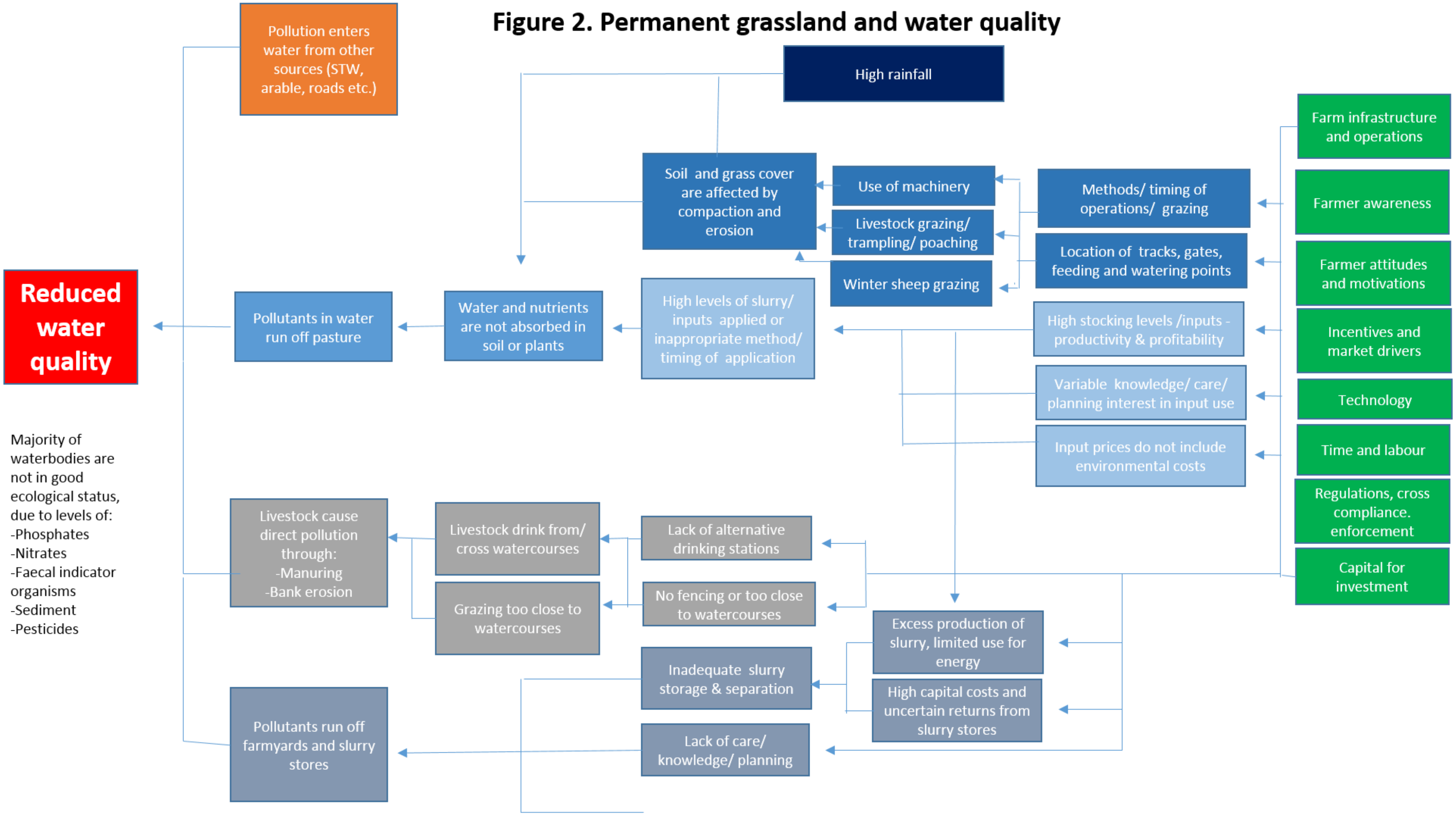
Many of the problems relating to permanent grassland are similar to those identified for improved pasture (Section 3), but are distinct from those related to temporary grassland that is ploughed and reseeded.

In North Devon, as well as the wet climate, these problems are driven by the intensity of farming systems, particularly dairying, which produces large volumes of slurry. Some partners argue that these exceed the carrying capacity of the land. Stocking rates and production patterns are driven by commercial pressures and low profit margins. Other important factors include farmer awareness of and attitudes towards pollution issues, the availability of capital for investments in slurry storage and treatment and other aspects of farm infrastructure, and the degree of regulatory enforcement. The

Taw River Improvement Project has helped to address some of these problems through investigations, farm advice, soil testing, nutrient management planning, and capital grants for riparian fencing and preparatory tree work, riparian buffer zones, alternative or improved livestock drinking points, soil tests, improvements to slurry or manure stores, culverts, farm track improvements and gate relocations (WRT, 2015).

Diffuse pollution can be managed using many different approaches according to location, farming system and resources available. These include precision farming (to target inputs and reduce waste), strategically sited grass buffer strips (to reduce overland sediment and nutrient runoff to watercourses) and anaerobic digestion and composting (to treat organic waste; UKNEA, 2011).

Figure 2. Permanent grassland and water quality



2.4. Possible Interventions

The following potential interventions are proposed by partners to address this problem:

PGW1. System change – converting farms away from intensive dairying and other systems. This is an outcome rather than a specific intervention, and might in practice be brought about by other interventions, e.g. relating to tighter regulatory enforcement (including enforcement of limits on inputs, methods of application, and nutrient planning and record keeping in the Nitrate Vulnerable Zone (NVZ)), payment for ecosystem services, and support for diversification through rural development schemes etc.

PGW2. Catchment based limits on nutrient inputs. Lower limits on nutrient inputs could be introduced for the NVZ; farmers could be allocated tradeable quota, which would need to be based on a reduction of per hectare limits currently set in the NVZ[4]. This would encourage more efficient nutrient use and cost-effective reductions to be sought; farmers reducing N inputs could sell quota. A similar approach has been applied in Lake Taupo, New Zealand (Duhon et al, 2015).

PGW3. Farm business planning and advice. Partners suggest there is a need to change the mind-set of many farmers in the area and to encourage a move away from a high input, high output approach. Profit maximisation may be achieved by focusing on value and not just volume, as well as by reducing input costs. There is opportunity to increase focus on enhancing prices farmers receive from milk, including through farm assurance schemes and negotiation with buyers incorporating environmental standards, and to look for opportunities to enhance margins by reducing input costs. Agronomic advice is often linked to sales of inputs; there is a need to counter this with independent advice that focuses on profitability rather than input use. However, it is recognised that efforts have already been made to raise awareness of soil management and nutrient planning in the past, and that achieving progress is likely to require education, training or awareness raising measures to be tied to more concrete regulatory or incentive measures.

PGW4. Shared equipment – Equipment to improve soil management such as soil aerators and umbilical slurry injection systems could be provided or demonstrated to farmers in conjunction with advisory services; alternatively equipment could be co-financed through rural development schemes and applications encouraged from groups of farmers.

PGW5. Agri-environment schemes - there is a need for better and more generous schemes that enhance payment for ecosystem services and are more attractive to the dairy sector. More support is required for buffer strips and fencing watercourses. Current agri-environment schemes are often not attractive to dairy farmers – there may be a need for enhanced payment rates in dairy systems, or other changes in the system, such as stricter regulation, that make them more attractive. There could be a role for new payment schemes – e.g. targeted challenge funds focused on achieving improvements in water quality and climate regulation at a local level. The area also needs to make the most of current funding schemes, including the Water Environment Grant (WEG), including through collaborative bids at catchment scale designed to enhance bathing waters.

PGW6. Market assurance. There is potential to work with milk buyers to strengthen environmental standards in return for a price premium. Continuing collaboration between farmers could help to achieve this.

PGW7. Farm diversification. Measures to promote tourism, local branding and product marketing through rural development programmes will help to reduce dependence on intensive farming and provide an incentive for farmers to enhance environmental performance. Diversified farm businesses would be less inclined to maximise dairy output at the expense of the environment, and would be encouraged to enhance environmental performance, especially if involved in tourism or branded activities.

[4] https://www.gov.uk/guidance/using-nitrogen-fertilisers-in-nitrate-vulnerable-zones

PGW8. Better regulatory enforcement. There is a need for much greater enforcement of existing legislation on water pollution, including through the enforcement of cross compliance measures. New approaches could be taken – e.g. requiring licencing of farm businesses to ensure that they have adequate infrastructure (e.g. slurry storage) and adhere to legislative requirements.

PGW9. Soil management. There is a need for further initiatives to raise awareness of the importance of soil as a capital asset, to encourage/ support the development and delivery of soil management plans, and to educate farmers about the financial impacts of damaging soil quality and function. However, it is recognised that efforts have already been made to raise awareness of soil management in the past, and that achieving progress is likely to require education, training or awareness raising measures to be tied to more concrete regulatory or incentive measures.

PGW10. Slurry management. Measures are needed to improve slurry storage and to reduce the amount of slurry being applied to land by encouraging alternative uses (such as for energy generation). These could include grants for slurry treatment/ separation/ anaerobic digestion, advice about slurry management, and regulatory enforcement (including NVZ Regulations and SSAFO Regulations - The Water Resources (Control of Pollution) (Silage, Slurry and Agricultural Fuel Oil) (England) Regulations 2010). Among other things, the NVZ Regulations require farmers to have a minimum of 5 months' slurry storage.

PGW11. Signposting existing tools. Most of the tools identified above (funding schemes, marketing initiatives, farm assurance, information, guidance etc.) all exist in some form – there would be benefit in signposting these and making the most of them. Partners suggest that consideration could be given to the development of web-based information resources focused on the Pioneer area and signposting the range of available information, funding and initiatives.

2.5. The Evidence

National evidence of the links between permanent grassland and water quality is strong, and the above causes of water quality issues are well evidenced at England and UK level. Key sources of evidence include:

Houses of Parliament – Parliamentary Office of Science and Technology. Diffuse Pollution of Water by Agriculture. Postnote October 2014

Natural England (2011) Protecting water from agricultural run-off: an introduction

UK National Ecosystem Assessment (2011) Technical Report

Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England

Cranfield University (2015) Research to develop the evidence base on soil erosion and water use in agriculture

Boardman J (2013) Soil Erosion in Britain: Updating the Record. Agriculture 2013, 3(3), 418-442

Environment Agency (undated) Manage your livestock so that they do not freely access watercourses. http://apps.environment-agency.gov.uk/static/documents/Utility/Ask5.pdf

Information on water quality in North Devon is available from the Environment Agency's Catchment Data Explorer - http://environment.data.gov.uk/catchment-planning/

While local evidence on the effects of permanent grassland on water quality is not comprehensive, a number of local sources evidence the causes identified above. These include:

Westcountry Rivers Trust (2015) The Taw River - Improvement Project. A Catchment Restoration Fund Project

Natural England, Defra, Environment Agency (2016). Catchment Sensitive Farming - South West River Basin District Strategy 2016 to 2021. Available at http://publications.naturalengland.org.uk/publication/7539405?category=45002, Last Accessed 09/12/2019.

North Devon's Biosphere Reserve (2014) The State of North Devon UNESCO World Biosphere Reserve

eftec (unpublished) Assessment of natural capital in the Landscape Pioneer (North Devon). Report for Defra.

3. Improved Pasture and Water Quality

3.1. Improved Pasture, Water Quality and Ecosystem Services

Improved pasture is defined here to include grassland that has been ploughed and re-seeded, as well as permanent grassland that has been improved for agricultural purposes (as covered in Section 2).

eftec (unpublished) identifies an area of approximately 97,000 hectares of improved pasture in the Pioneer area, as well as 58,000 hectares of permanent grassland (much of which has been agriculturally improved); as the predominant land use in North Devon, the management of improved pasture strongly influences the quality of water in the area.

The links between improved pasture, water quality and ecosystem services are similar to those described for permanent grassland in Section 2.1 above.

3.2. The Problem

The problems for water quality caused by improved pasture are similar to those described for permanent grassland in Section 2.2 above. Improved pasture is the predominant land use in North Devon and its management strongly influences the quality of water in the area.

3.3. The Causes

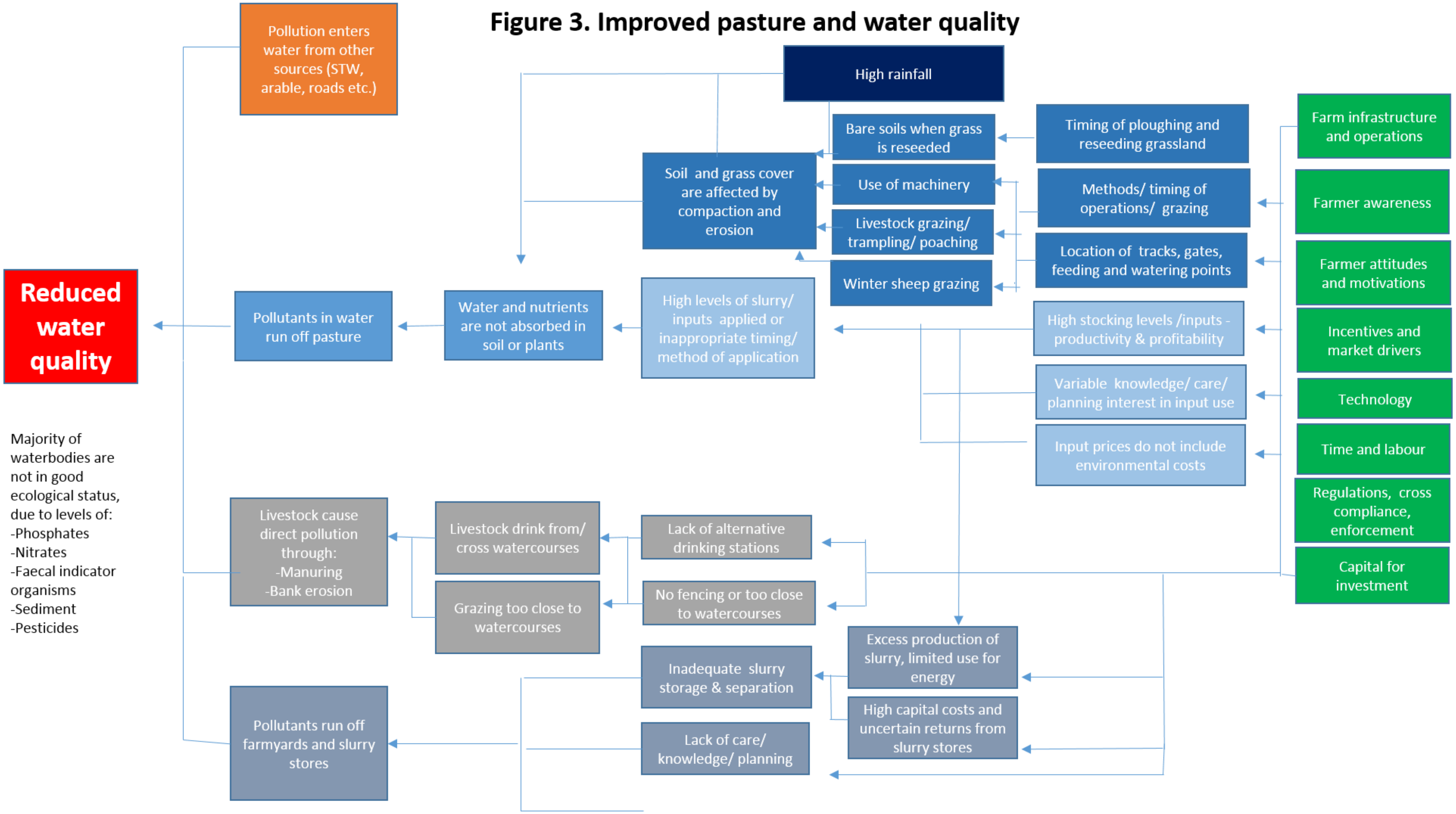
Water quality issues relating to improved pasture include problems resulting from grassland management, and from the ploughing and reseeding of grasslands. The causes identified are therefore a combination of those identified in the root cause analyses for “Permanent grassland and water quality” and “Arable land and water quality”.

As well as the causes described for permanent grassland in Section 2.3 above, improved pasture that is cultivated and reseeded may be subject to increased problems of soil erosion and run-off, especially from fields susceptible to erosion or through inappropriate operations (e.g. working up slopes) (Cranfield University, 2015). The timing of grass reseeds is also a factor affecting erosion risk, with spring reseeds in general reducing erosion risk compared to those undertaken in autumn (Defra, 2005).

Defra (2005) suggested a number of measures that can be taken to reduce the risk of erosion and run-off from grassland reseeds:

- Undertaking surface pasture improvements as an alternative to re-seeding on vulnerable land;
- Removing compaction before establishing the grass, and timing operations to minimise risks of further compaction;
- Reseeding in the spring where possible;
- Where grass is to follow a spring cereal crop, undersowing the cereal;
- Sowing early enough to achieve a minimum of 25% cover before early winter;
- Avoiding overworking the soil during seedbed preparation;
- Avoiding grazing recently-re-seeded land until the sward is well established;
- Removing stock when soils are wet.

Figure 3. Improved pasture and water quality



3.4. Possible Interventions

The following potential interventions are proposed by partners to address this problem:

IPW1. System change. As for permanent grassland.

IPW2. Catchment based limits on nutrient inputs. As for permanent grassland.

IPW3. Education and awareness raising. In addition to the needs identified for permanent grassland, there is a need to raise awareness about the effects of timing of reseeds. Spring reseeds achieve quicker root growth and reduce erosion, but lead to later first silage crop.

IPW4. Shared equipment. As for permanent grassland.

IPW5. Agri-environment. As for permanent grassland.

IPW6. Marketing and farm assurance schemes. As for permanent grassland.

IPW7. Farm diversification. As for permanent grassland.

IPW8. Stricter regulatory enforcement. As for permanent grassland.

IPW9. Soil management. As for permanent grassland.

IPW10. Slurry management. As for permanent grassland.

IPW11. Signposting existing tools. As for permanent grassland.

3.5. The Evidence

National evidence of the links between improved pasture and water quality is strong, and the above causes of water quality issues are well evidenced at England and UK level. Key sources of evidence include:

POST (2014) Houses of Parliament – Parliamentary Office of Science and Technology. Diffuse Pollution of Water by Agriculture. Postnote October 2014

Natural England (2011) Protecting water from agricultural run-off: an introduction

UK National Ecosystem Assessment (2011) Technical Report

Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England

Cranfield University (2015) Research to develop the evidence base on soil erosion and water use in agriculture

Boardman J (2013) Soil Erosion in Britain: Updating the Record. Agriculture 2013, 3(3), 418-442

Information on water quality in North Devon is available from the Environment Agency's Catchment Data Explorer - http://environment.data.gov.uk/catchment-planning/

While local evidence on the effects of improved pasture on water quality is not comprehensive, a number of local sources evidence the causes identified above. These include:

Westcountry Rivers Trust (2015) The Taw River - Improvement Project. A Catchment Restoration Fund Project

Natural England, Defra, Environment Agency (2016). Catchment Sensitive Farming - South West River Basin District Strategy 2016 to 2021. Available at http://publications.naturalengland.org.uk/publication/7539405?category=45002, Last Accessed 09/12/2019.

North Devon's Biosphere Reserve (2014) The State of North Devon UNESCO World Biosphere Reserve

eftec (unpublished) Assessment of natural capital in the Landscape Pioneer (North Devon). Report for Defra.

4. Improved Pasture and Climate Regulation

4.1. Improved Pasture and Climate Regulation Services

As in Section 3, improved pasture is defined here to include both improved permanent grassland, and temporary grassland which is cultivated and reseeded or forms part of arable rotations on dairy and livestock farms.

Grasslands play an important role in sequestering and storing carbon, and have the highest carbon stock of any UK broad habitat (NEA, 2011). Improved pasture is the dominant land use in North Devon, and therefore potentially plays a valuable role in contributing to climate regulation services. eftec (unpublished) identifies an area of approximately 97,000 hectares of improved pasture in the Pioneer area, as well as 58,000 hectares of permanent grassland (much of which has been agriculturally improved).

4.2. The Problem

Evidence indicates that the management of grassland greatly affects its capacity to store carbon and contribute to climate regulation. In particular, the intensification of grassland management has tended to reduce levels of soil carbon over time nationally (Ward et al, 2016), while soil carbon levels also tend to be reduced by compaction and cultivation (Natural England, 2012). Evidence from North Devon is limited, though partners report that climate regulation services are likely to be reduced by intensive management of pasture as well as impacts on soil through compaction and erosion. There is also evidence that Culm grassland holds higher levels of carbon than intensively managed pasture (University of Exeter et al, undated). The evidence therefore suggests that the intensification and improvement of pasture in North Devon is likely to have reduced its delivery of climate regulation services over time.

4.3. The Causes

The principal causes of reduced climate regulation related to improved pasture are:

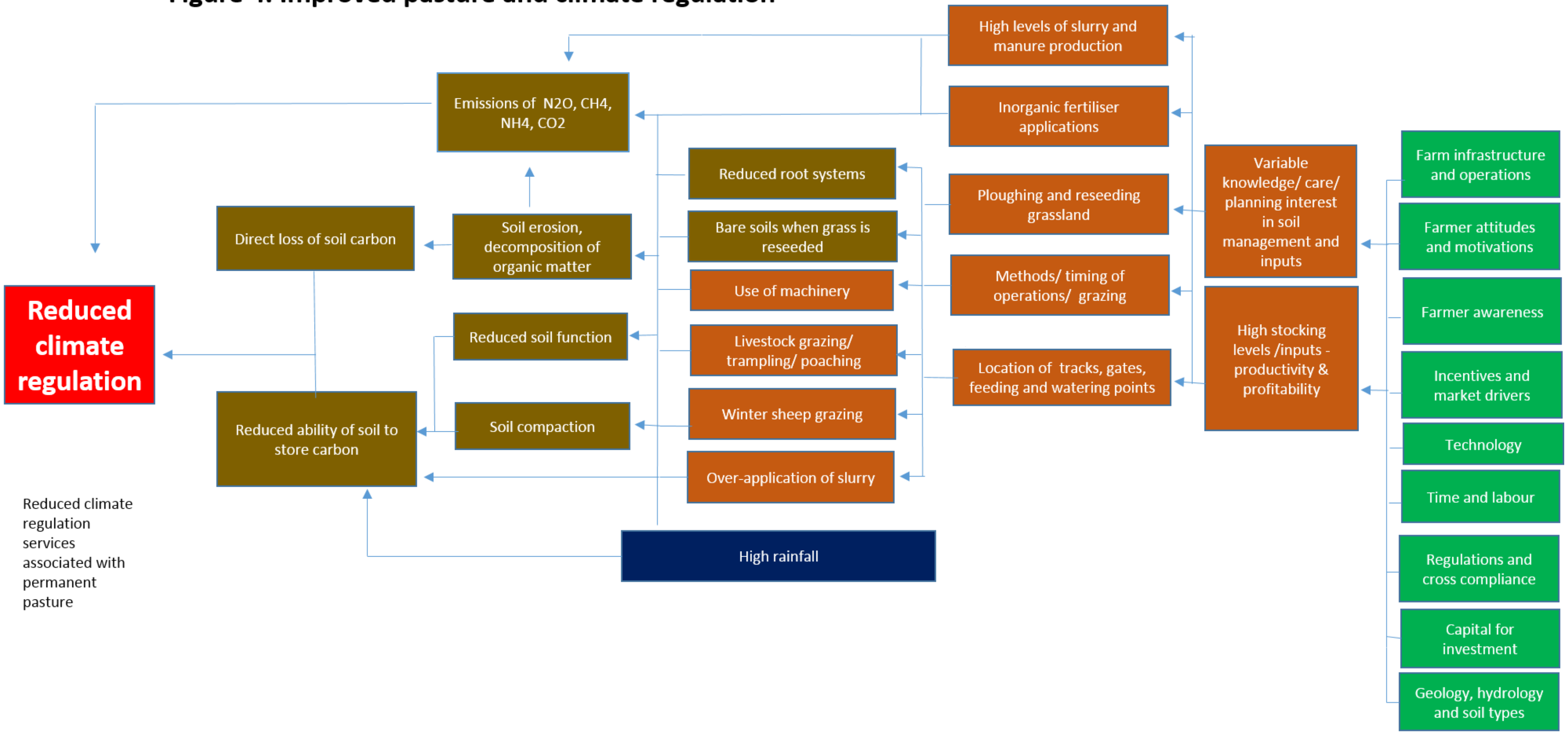
- **Direct emissions of greenhouse gases**, including nitrogen oxides, methane, ammonia and carbon dioxide. The main carbon losses from agricultural systems result from increased rates of decomposition of soil organic matter and losses via erosion of the topsoil, which contains a greater percentage of organic carbon (Natural England, 2012). Other major sources of emissions from pasture systems include organic and inorganic fertilisers, animal digestive systems, manures and slurries, soil processes and machinery use (UKNEA, 2011). Emissions are increased by high stocking rates and levels of production of manures and slurry. The large-scale loss of permanent grassland in the UK during the 20th century is believed to have resulted in large releases of carbon. Conversion from grassland to arable land can produce additional emissions of between 3.48 to 6.23 tonnes of CO_2 equivalent per hectare per year (Natural England, 2012). Reversion of a temporary grassland / arable rotation to permanent grassland will tend to lead to an increase in carbon sequestration - the cessation of cultivation will reduce carbon dioxide losses (UKNEA, 2011; Natural England, 2012). This is an important issue in North Devon where a large proportion of improved pasture is reseeded (eftec, unpublished).

- **Reduced soil quality and function**. The quality and functioning of the soil are affected by erosion, compaction and reduced biodiversity, limiting root systems and affecting the ability of the soil to take up nutrients and store carbon (POST, 2015; Lal, 2015). Soil loss and run-off are increased if soils are left bare or are compacted, particularly at times of high rainfall.

> Soils are exposed when grassland is cultivated and reseeded. They may be compacted by use of heavy machinery or pressure from livestock, including winter grazing by sheep. These pressures are influenced by the timing and methods of operations and grazing regimes, particularly in the winter months. The layout of the farm and its infrastructure is also a factor – for example the location of gates, tracks, feeding and water stations affects movements of livestock and machinery and may contribute to pressure points where erosion and compaction are caused. Land use reversion, erosion control, low or zero tillage, organic matter additions and rewetting drained land are examples within the literature of measures that can be taken to improve agricultural carbon storage (Natural England, 2012).

In North Devon, direct evidence is limited, but partners note that these problems are driven by the intensity of farming systems, particularly dairying, which produces large volumes of slurry, as well as being exacerbated by the wet climate. Some partners argue that the production of slurry exceeds the capacity of the land to absorb it. Reduced soil quality and function limit the ability of the soil to store carbon. Stocking rates and production patterns are driven by commercial pressures and low profit margins. Other important factors include farmer awareness of and attitudes towards soil management and climate issues, as well as the availability of capital for investments in slurry storage and treatment and other aspects of farm infrastructure.

Figure 4. Improved pasture and climate regulation



Reduced climate regulation services associated with permanent pasture

4.4. Possible Interventions

The following potential interventions are proposed by partners to address this problem:

IPC1. System change. As for permanent grassland and water quality.

IPC2. Catchment based limits on nutrient inputs. As for permanent grassland and water quality.

IPC3. Education and awareness raising. As for improved pasture and water quality.

IPC4. Shared equipment. As for permanent grassland and water quality.

IPC5. Agri-environment. As for permanent grassland and water quality.

IPC6. Marketing and farm assurance schemes. As for permanent grassland and water quality.

IPC7. Farm diversification. As for permanent grassland and water quality.

IPC8. Stricter regulatory enforcement. As for permanent grassland and water quality.

IPC9. Soil management. As for permanent grassland and water quality.

IPC10. Slurry management. As for permanent grassland and water quality.

IPC11. Signposting existing tools. As for permanent grassland and water quality.

4.5. The Evidence

Key sources of national and international evidence include:

UK National Ecosystem Assessment (2011) Technical Report

Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources. Natural England Research Report NERR043

Parliamentary Office of Science and Technology (2015) Securing UK Soil Health. Post Note no 502, August 2015

Ward S E, Smart S M, Quirk H, Tallowin J R B, Mortimer S R, Shiel R S, Wilby A and Bardgett R G (2016) Legacy effects of grassland management on soil carbon to depth.
http://eprints.lancs.ac.uk/78464/1/Ward_et_al_Accepted_author_manuscript.pdf

Lal R (2015) Restoring Soil Quality to Mitigate Soil Degradation. Sustainability 2015, 7, 5875-5895; doi:10.3390/su7055875

There is limited local evidence of carbon regulating services by permanent pasture, though the experience of local partners points to issues relating to soil and nutrient management locally.

Evidence of enhanced carbon storage in Culm Grasslands and its value is presented in:

University of Exeter and Devon Wildlife Trust (undated) Impact of Culm Grasslands upon Water and Soil Quality.
http://www.northdevonbiosphere.org.uk/uploads/1/5/4/4/15448192/culm_water__soil_quality_-_dwt_and_exeter_university.pdf

Devon Wildlife Trust (2015) The Economic Value of Ecosystem Services Provided by Culm Grasslands

Data on the extent of improved pasture in North Devon are presented in:

eftec (unpublished) Assessment of natural capital in the Landscape Pioneer (North Devon). Report for Defra.

This report identifies an area of approximately 58,000 hectares of permanent grassland and a further 97,000 hectares of improved pasture in the North Devon Landscape Pioneer.

5. Arable Land and Water Quality

5.1. Arable Land, Water Quality and Ecosystem Services

Diffuse pollution from arable land contributes to reductions in water quality and the associated losses of ecosystem services described in Section 2 above.

5.2. The Problem

Farming is a major contributor to water pollution nationally, and is estimated to account for approximately 60 per cent of the nitrates, 25 per cent of the phosphorus and 70 per cent of the sediments entering our waters (Natural England, 2011; POST, 2014b). Diffuse pollution from agriculture and rural land use is directly attributed to 28% of failures to meet Water Framework Directive standards (POST, 2014b). Nationally, sediment and phosphorus loads are generally higher under arable systems than grassland ones (UKNEA, 2011).

Arable land, while accounting for a smaller area than permanent grassland and improved pasture, is a significant land use in the North Devon Biosphere Reserve area, covering a total of approximately 21,000 hectares (NDBR, 2014; unpublished, 2017). The area has some specialist arable farms, as well as dairy farms which manage some of their land as arable.

Arable land contributes significantly to diffuse water pollution in the area. The Environment Agency's Catchment Data Explorer indicates that in 2016, only 3 out of 42 water bodies in the Torridge catchment were in good ecological status, with 32 classed as moderate and 7 as poor. Agriculture contributed to 22 out of 87 reasons for not achieving good status, being the second largest cause behind the water industry (with discharges from sewage treatment plant being the most frequent pressure). A similar picture applies to the Taw catchment and North Devon streams. Diffuse pollution, involving nutrients, sediment and phosphate, is the primary pressure in the agriculture sector, although agricultural point sources were implicated in two failures in the Taw catchment. Although most reasons for failures in the agriculture sector are identified as being caused by livestock, poor management of nutrients and soil are also identified in a small number of cases. Problem pollutants include phosphates, nitrates, faecal indicator organisms, sediment and pesticides (Natural England, Defra and Environment Agency, 2016).

5.3. The Causes

Water quality issues result from **pollutant run-off and soil loss from arable land** (UKNEA, 2011; Natural England, 2011; POST, 2014b). This is often associated with periods of high rainfall and is often exacerbated by:

- **High levels of inputs of slurry and fertilisers.** Excess nitrogen compounds from fertilisers and manures may be released as nitrate leaching to ground and surface waters (UKNEA, 2011). Phosphorus from fertilisers tends to bind with soil particles, so sediment loss is associated with elevated phosphorus concentrations in waters and accounts for around 29% of phosphates in rivers in the UK (UKNEA, 2011). The timing of slurry application, and the application method can also significantly affect the amount of runoff from fields (POST, 2014b). The active monitoring of soil nutrient and moisture levels and crop health allows the precise application of fertilisers and pesticides to crops as they are needed. Minimising the amount of chemicals applied to crops reduces their contribution to diffuse water pollution (POST, 2014b).

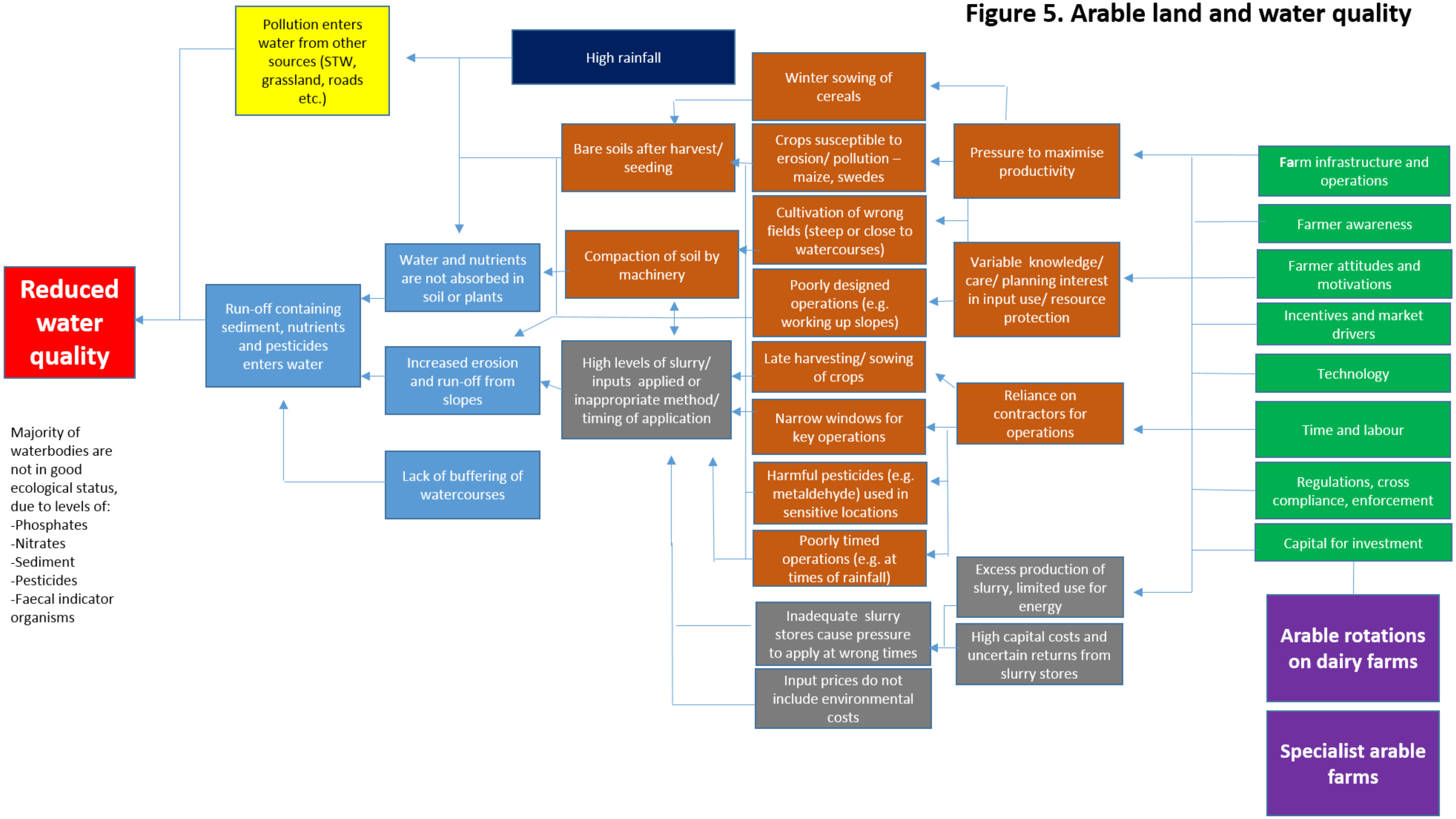
- **Soils affected by compaction and erosion.** Run-off and soil loss are increased if soils are left bare or are compacted, particularly at times of high rainfall (Defra, 2005; Cranfield University, 2015). Soils may be left bare after harvest and sowing. Some crops such as maize are particularly prone to erosion as a result of the exposure of soil underneath them. Planting crops that are appropriate to the location and soil type helps reduce pollution inputs – e.g. maize planted on steep slopes is a significant source of sediment loss (POST, 2014b). The timing of operations is also important; winter sowing of cereals and late harvesting of crops exposes soil to rainfall during the winter months (Cranfield University, 2015). Many dairy farms with arable land rely on contractors for harvesting and cultivation, which can make it more difficult to time operations correctly to avoid times of high rainfall. Erosion and run-off may also be increased by cultivating fields susceptible to erosion or through inappropriate operations (e.g. working up slopes).

Socio-economic factors are among the root causes of soil erosion and water pollution, encouraging the intensification of production and inappropriate use and management of land. Buyers may put pressure on growers to supply a given quantity and quality of crops on demand, so putting pressure on farmers/land managers to grow unsuitable crops and/or to access the land when conditions are less than ideal (Boardman, 2013; Cranfield University, 2015).

In North Devon, as well as the wet climate, these problems are driven by the intensity of farming, with much arable land being managed as part of intensive dairy farming systems.

Diffuse pollution can be managed using many different approaches according to location, farming system and resources available. These include precision farming (to target inputs and reduce waste), minimum tillage (to can reduce the transport of sediment and associated phosphorus to water via surface runoff), and strategically sited grass buffer strips (to reduce overland sediment and nutrient runoff to watercourses) (UKNEA, 2011).

Figure 5. Arable land and water quality



Majority of waterbodies are not in good ecological status, due to levels of:
-Phosphates
-Nitrates
-Sediment
-Pesticides
-Faecal indicator organisms

5.4. Possible Interventions

The following potential interventions are proposed by partners to address this problem:

AWQ1. Soil management. Partners argue that all farms should have a soil management plan. Further education and training of farmers regarding the importance of good soil management would be beneficial; however there is an issue that only those interested attend events.

AWQ2. Regulation and enforcement. Proper enforcement of existing rules is needed. There would be benefit in new, simple rules – for example a requirement to rough cultivate if harvest occurs after October; targeted local bans on certain pesticides such as metaldehyde would be beneficial. Some fields should be taken out of cultivation – a rigorous approach to regulatory enforcement would help to achieve this.

AWQ3. Marketing and farm assurance. Working with buyers to achieve price premium for good environmental standards.

AWQ4. Mapping of land use. Producing a map of suitable land uses across North Devon, identifying those fields which should not be cultivated or should be managed with extra care, could be a powerful tool. It could be shared with farmers, regulators and buyers. This could be useful not just for arable but also inform grassland management and help to identify best sites for woodland planting and habitat creation.

AWQ5. Agri-environment and farm capital grants. More generous funding/ higher payment rates for reversion of arable to grassland, planting of buffer strips, moving gateways etc. would help to enhance uptake.

5.5. The Evidence

National evidence of the links between arable land and water quality is strong, and the above causes of water quality issues are well evidenced at England and UK level. Key sources of evidence include:

POST (2014) Houses of Parliament – Parliamentary Office of Science and Technology. Diffuse Pollution of Water by Agriculture. Postnote October 2014

Natural England (2011) Protecting water from agricultural run-off: an introduction
UK National Ecosystem Assessment (2011) Technical Report

Defra (2005) Controlling soil erosion: A manual for the assessment and management of agricultural land at risk of water erosion in lowland England

Cranfield University (2015) Research to develop the evidence base on soil erosion and water use in agriculture

Boardman J (2013) Soil Erosion in Britain: Updating the Record. Agriculture 2013, 3(3), 418-442

Information on water quality in North Devon is available from the Environment Agency's Catchment Data Explorer - http://environment.data.gov.uk/catchment-planning/

While local evidence on the effects of improved pasture on water quality is not comprehensive, a number of local sources evidence the causes identified above. These include:

Westcountry Rivers Trust (2015) The Taw River - Improvement Project. A Catchment Restoration Fund Project

Natural England, Defra, Environment Agency (2016). Catchment Sensitive Farming - South West River Basin District Strategy 2016 to 2021. Available at http://publications.naturalengland.org.uk/publication/7539405?category=45002, Last Accessed 09/12/2019.

North Devon's Biosphere Reserve (2014) The State of North Devon UNESCO World Biosphere Reserve

eftec (unpublished) Assessment of natural capital in the Landscape Pioneer (North Devon). Report for Defra.

6. Coastal Margins and Cultural Services

6.1. Coastal Margins and Cultural Ecosystem Services

The North Devon coast and its rich and varied landscapes and habitats provide a range of valuable ecosystem services. These include important cultural services – the coast is attractive for residents and visitors and contributes substantially to North Devon's economy through tourism and recreation. Tourism is a vital part of the local economy with visits to North Devon and Torridge estimated at 6 million per year, attracting total tourism expenditure of approximately £0.56 million annually (North Devon Council and Torridge Council, 2018). eftec (unpublished) also cited alternative estimates from the GB Tourist Statistics 2015 and GB Day Visitor Statistics 2015, that 7.7m tourist and day visitors to the North Devon area spend a total of £257 million per year.

Coastal margin habitats in the Biosphere area are estimated to amount to approximately 3,000 hectares, including around 260 hectares of coastal wetlands, 2000 hectares of estuary and 1,000 hectares of dunes (eftec, unpublished).

6.2. The Problem

While the value of North Devon's coast and the services it provides to people are widely recognised, they are subject to a wide range of threats and pressures, which, if not addressed, could have adverse implications on the economy, local communities and the environment over time.

6.3. The Causes

Nationally, pressures on coastal habitats are documented in the UK National Ecosystem Assessment (2011) and include:

- **Sea level rise**, caused by climate change, resulting in inundation of low-lying coastal areas, accelerated erosion of beaches, dunes and soft cliffs exposed to significant wave action, more frequent coastal flooding and saline intrusion, and coastal squeeze (where natural habitats, such as dunes and saltmarshes, are constrained by steeply rising ground or coastal defences on their landward side, preventing natural landward translation);

- **Effects of climate change and air pollution** on coastal habitats and species;

- **Tourism**, which benefits local economies can put pressure on resources, such as water or waste treatment facilities, increase land-claim for infrastructure development, damage sensitive ecosystems, cause pollution and littering, and have adverse social impacts, particularly when tourist numbers are strongly seasonal or greatly exceed the local population; and

- **Coastal development**, including recent growth in housing demand caused by strong net in-migration to coastal towns of people of working age and people choosing to retire by the sea.

In North Devon, partners identify a range of existing and potential pressures on the landscape, natural environment, tranquillity and character of the coast. These include:

- **Ongoing development pressures**, resulting from increased demand for housing, tourism development, renewables, aquaculture and other economic activities;

- **Pressures from visitors and coastal users**, resulting in path erosion, noise, litter and disturbance to wildlife;

- **Under-management** of some coastal habitats, such as dunes, heathland and grassland, resulting in scrub encroachment and often linked to the marginal viability of land for grazing;

- **Physical impacts on the coast**, including erosion and coastal squeeze, resulting from extreme weather events, sea level rise and disruption of coastal processes, and linked to climate change;

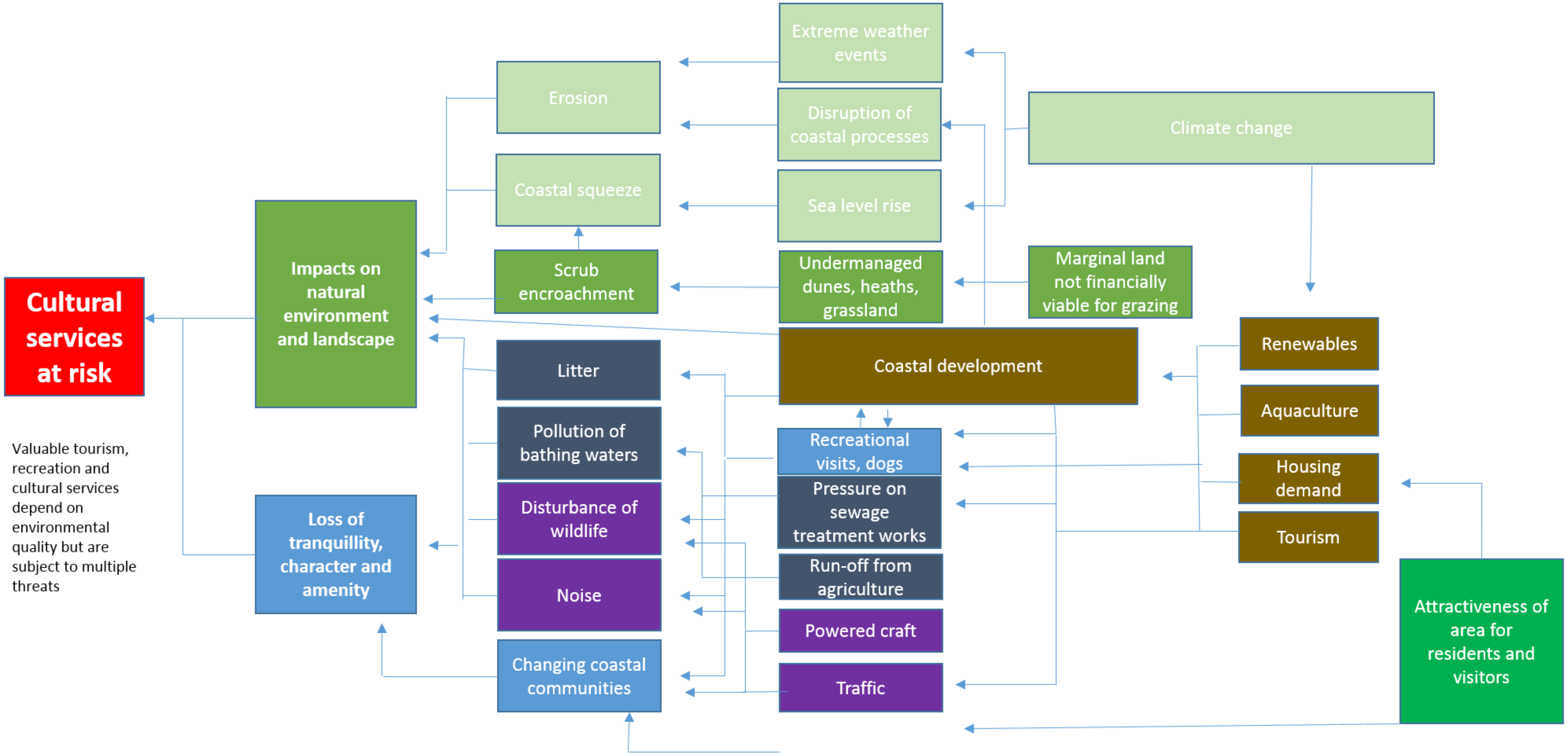
- **Pollution of beaches and coastal waters**, resulting from agriculture and sewage treatment works (some of which face capacity pressures);

- **Changes in the character of coastal communities**, which are affected by 2nd homes, new development, traffic and visitor numbers.

The Shoreline Management Plan (NDASCAG, 2010) identifies issues relating to long-term sustainable defence provision at Westward Ho!; managed realignment at Northam Burrows including requirement for set-back defences to protect features such as the landfill site at the northern end of the Burrows, improving drainage of the Burrows, and land use adaptation; the need for managed realignment within the Taw/Torridge Estuary and the issues this raises for sediment dynamics within the estuary and adjacent open coast areas, as well as the impact on the Tarka Trail; and investigation and management of erosion risk along the southern side of Saunton Down.

Bathing water quality information is provided by the Environment Agency on its bathing water quality webpages. Bathing water quality is currently rated poor at Ilfracombe Wildersmouth and Combe Martin. Both sites are subject to short term pollution when heavy rainfall washes faecal material into the sea from livestock, sewage and urban drainage via rivers and streams. The risk of encountering reduced water quality increases after rainfall and typically returns to normal after 1-3 days. Forty two warnings advising against swimming due to an increase risk of short term pollution were issued in 2017 for Ilfracombe Wildersmouth bathing water, while 47 warnings were issued for Combe Martin.

Figure 6. Coastal margins and cultural services



Valuable tourism, recreation and cultural services depend on environmental quality but are subject to multiple threats

6.4. Possible Interventions

The following potential interventions are proposed by partners to address this problem:

CMC1. Tourism strategy. There is a risk that tourism growth could damage the environment and lead to excessive congestion, with negative effects on the tourism experience. Partners suggest that North Devon should develop a tourism strategy focusing on maximising value rather than volume, and seeking to develop a sustainable tourism offer. The North Devon Marketing Bureau could be the vehicle to achieve this. There is a need initially for a debate in the local community and tourism sector about what type of tourism North Devon wants to develop. A green tourism strategy could have a number of strands including increasing the value and benefit of the local tourism sector, identifying tourism developments/ facilities/ initiatives that should be encouraged/ discouraged, raising awareness of businesses and visitors regarding environmental pressures and issues, greening of tourism businesses (energy, waste, transport, procurement etc), codes of conduct for businesses and visitors etc.

CMC2. Visitor payback/ giving – there has been some discussion around the idea of a visitor payback scheme. This could be voluntary and raise funding for and awareness of local environmental improvements. It could help to strengthen linkages and raise awareness/ engagement between businesses, visitors and the natural environment. It could form part of a green tourism strategy. Businesses would need to be convinced about the benefits and the value of the investments funded.

CMC3. Managed realignment is needed to address the issue of coastal squeeze and loss of coastal habitats. Schemes have been proposed, especially in the estuary. To build support, there is a need to raise public awareness of the benefits and importance of the issue.

CMC4. Net gain – this is existing practice in North Devon following the biodiversity offsetting pilot. It will be strengthened by reinforced national commitments to biodiversity net gain in the 25YEP; it would usefully be extended to intertidal habitats, offsetting the effects of sea level rise and coastal squeeze.

CMC5. Investment in upgrading sewage infrastructure in Ilfracombe would help to improve bathing water quality – this would require investment by South West Water in addressing problems caused by storm water overflows and misconnections.

CMC6. Measures to tackle diffuse water pollution from agriculture, as set out above, will help to improve bathing water quality.

CMC7. Codes of conduct, backed by education, monitoring and policing, can help to address problems of disturbance by jet skis and powered craft.

CMC8. Traffic management. Problems could be addressed by park and ride schemes at honeypot sites. It would help to have a capacity study to inform traffic planning.

6.5. The Evidence

Nationally, the UK National Ecosystems Assessment (2011) presents evidence on the value of coastal ecosystem services, and the range of trends and pressures affecting them.

Local evidence on the above pressures and their causes is not comprehensive. However, useful local sources include the Shoreline Management Plan (particularly for issues relating to coastal erosion, coastal squeeze and managed realignment), State of the Biosphere report (which documents some of the human pressures on the coast) and the State of Devon's Nature report which documents the condition of, and pressures on, a range of coastal ecosystems.

Environment Agency – Bathing Water Quality. https://environment.data.gov.uk/bwq/profiles/
North Devon and Somerset Coastal Advisory Group (NDASCAG) (2010) Shoreline Management Plan Review (SMP2) Hartland Point to Anchor Head. Summary of Draft Final SMP

eftec (unpublished) Assessment of natural capital in the Landscape Pioneer (North Devon). Report for Defra.

Devon Local Nature Partnership (2014) State of Devon's Nature 2013

North Devon's Biosphere Reserve (2014) The State of North Devon UNESCO World Biosphere Reserve
Visit England (undated) South West England and Domestic Tourism.
https://www.visitbritain.org/sites/default/files/vb-corporate/Documents-Library/documents/England-documents/south_west_2015.pdf

North Devon Council and Torridge Council (2018). Northern Devon Tourism Strategy 2018-2022. Available at https://www.northdevon.gov.uk/media/379003/northern-devon-tourism-strategy-final.pdf. Last accessed 12/12/2019.

7. Woodland and Climate Regulation

7.1. Woodland and Climate Regulation Services

Carbon sequestration is one of the most important regulating services provided by woodlands. The total carbon stock in UK forests (including soils) is around 800 megatonnes of carbon (Mt C), and is estimated to be a further 80 Mt C in timber and wood products (UK NEA, 2011). Long term average sequestration is estimated at around 14 t CO2/ha/yr for coniferous forest and around 7 t CO2/ha/yr for oak forest. The social value of net carbon sequestration by UK woodlands is currently at least double the market value of wood production per hectare; and the total value of net carbon sequestration by UK woodlands planted after 1921 increased more than six-fold over the period between 1945 and 2004, falling thereafter. The UK NEA estimated that carbon sequestration currently has the highest annual social value of all woodland ecosystem services (UKNEA, 2011). eftec (2015) estimated the annual value of carbon sequestration at £341 million for broadleaves and £372 million for conifers in Great Britain in 2012; this greatly exceeded the annual value of biomass for timber but was less than the estimated value of recreational services provided by woodland.

7.2. The Problem

Partners argue that the value of climate regulation services provided by woodlands in North Devon is limited by the limited extent of woodlands in the area. It is estimated that there are currently approximately 5,000 ha of coniferous and 30,000 ha of broadleaved woodland in North Devon; woodlands therefore account for approximately 15% of the terrestrial land area of the Biosphere Reserve (eftec, unpublished). This is small compared to the area of farmland, but exceeds the England national average of 10% woodland cover (Forestry Commission, 2017). The condition of existing woodlands in the area is affected by a lack of management, which is believed to limit the delivery of climate regulation services.

7.3. The Causes

Nationally, tree cover of one form or another is believed to have dominated the landscape in the UK in the pre-Neolithic period. However, the post-glacial history of native woodland in the UK is largely one of loss, degradation and fragmentation, including large scale clearance for agriculture. By the beginning of the 20th Century, woodland comprised less than 5% of the country (UKNEA, 2011). Since 1945, there has been a significant increase in forest cover through new planting and forest creation, though the rate of increase slowed since the mid-1980s, while there has also been a shift towards expansion of broadleaved and native woodland (UKNEA, 2011).

UKNEA (2011) identifies the key threats to semi-natural woodland as overgrazing, habitat fragmentation and isolation, invasion by non-native species, unsympathetic forestry practices, lack of appropriate management, air pollution and new pests and diseases. In addition, more localised pressures include losses to built development (including quarries), inappropriate game management, recreational pressures and drainage or water quality issues. In the long-term, species and assemblages will also be affected by climate change.

Natural England (2012) notes that the condition of many semi-natural woods in England is threatened by neglect or inappropriate management. The main reasons that woodlands are in unfavourable condition, which may influence the carbon cycle, include excessive grazing (deer in the lowlands, livestock in the uplands) and inappropriate forestry and woodland management. Semi-natural woodlands in good condition should have appropriate structural complexity and variability, show natural regeneration and locally distinctive vegetation composition. The choice of management options and species has a significant impact on the potential of a woodland to store carbon. On the whole, unmanaged forest nature reserves tend to have high stocks of carbon but to have low rates of annual carbon sequestration compared to forestry systems. A number of factors affect the potential of woodlands to sequester carbon. Grazing impacts on woodland flora but also on the carbon stock by removing biomass in the understory. The large amount of litter in forest soils contributes to their carbon sequestration capacity (Natural England, 2012).

Only about 20% of the gross annual increment of broadleaves in the UK is currently harvested, so that production could increase substantially from the existing woods (UKNEA, 2011). There is considerable interest in encouraging further use of this resource, but there are thought to be operational, market and attitudinal barriers to harvesting a greater proportion of the increment; the fragmented ownership and typical location of small woodlands within an agricultural landscape are particular barriers. The only market that seems likely to be able to expand sufficiently to take advantage of this potential resource is wood-fuel. The markets for traditional coppice products remain steady, or are increasing slightly, and seem unlikely to increase much. More recently, the general firewood market has been buoyant, as has the demand for wood-burning stoves and charcoal for barbeques (UKNEA, 2011).

The ability of trees, woodlands and forests to provide ecosystem services is dependent on both the type of management and the location of wooded patches in the landscape, since different forest management systems and woodland types lead to differing outcomes. The climate change mitigation benefits resulting from carbon sequestered in the trees and soil is dependent on silvicultural operations such as site preparation, species choice and harvesting methods (Forestry Commission, 2015).

UKNEA (2011) highlights the cost effectiveness of woodland planting as a means to sequester carbon and mitigate climate change, but notes that a lack of markets for carbon sequestration currently limit the incentives for landowners to increase provision of this ecosystem service or to maintain existing carbon storage. While carbon sequestration is the most valuable ecosystem service delivered by woodlands in the UK, it remains largely a non-market value (UKNEA, 2011).

Locally, a report by the North Devon Nature Improvement Area (2015) estimated that nearly 60% of the NIA's woodland is undermanaged, and suggested that good woodland management and marketing of woodland products, such as woodfuel, will bring benefits to the local economy and improve local biodiversity. Damage from grey squirrels poses a serious threat to the viability of establishing productive woodlands in the NIA, alongside deer damage. The NIA has established an ambitious woodland creation target. The availability and levels of grants determine whether landowners are willing to create new broadleaved woodland. Much work remains to be done in developing markets and encouraging broadleaved woodland management. It was noted that issues of deer and squirrel damage, plus tree diseases such as ash dieback, bring additional challenges to meeting the NIA's woodland planting and woodland management aspirations.

Local partners identify the following causes of reduced climate regulation services by woodlands in North Devon:

- The area of woodland is limited by low rates of new planting, as well as historic losses. Low rates of woodland planting are believed to be a result of the limited attractiveness of woodlands compared to agriculture. This is linked to a range of factors including CAP subsidies, limited payments for ecosystem services, and poor market returns from woodlands;

- The delivery of climate regulation services by existing woodlands is believed to be limited by a range of factors, such as poor woodland structure and the effects of pests and diseases. The under-management of woodland, as well as poor woodland design and clear-fell management, are believed to have resulted in even aged stands which fail to meet their potential to sequester carbon. There are a range of barriers, including a (perceived) lack of markets for woodland products, a lack of machinery and processing capacity, barriers relating to the small size and accessibility of woods, inadequate management grants, time constraints among woodland managers, and a lack of fit with owners' core (farming) business.

7.4. Possible Interventions

The following possible interventions were identified by Pioneer partners for woodlands and ecosystem services – with the same interventions contributing to both climate and water regulation:

WES1: Reform of agricultural subsidies is key to making woodland more attractive compared to agricultural land use. Land management schemes post Brexit should seek to remove the disincentives that the CAP currently has for woodland creation.

WES2: Enhanced support for woodland planting and management, including greater rewards for ecosystem service delivery. Increasing incentives for creating and managing woodland in the right places, as well as for management practices that enhance woodland soils and water management, would help to enhance service delivery.

WES3: Mapping of the best locations for new woodland creation – this would help to maximise benefits for water and climate and could inform advice to landowners, and development of targeted support schemes.

WES4: Advice, training and skills development – for woodland owners, managers and contractors – is important to address barriers to management and promote access to markets for wood products. There is a need to develop woodland management, processing, marketing and conservation skills; to encourage woodland managers to add value to timber and shorten supply chains; and to signpost market opportunities. Market development could include opportunities for non-timber forest products (wood fuel, venison, mushrooms etc).

WES5: Collaboration/ co-operation – encouraging woodland owners to work together can help to bring economies of scale – e.g. through sharing of machinery and know-how, larger scale production and marketing, co-ordinated approaches to provision of ecosystem services.

7.5. The Evidence

Evidence about the ecosystem services delivered by woodlands in the UK, and pressures affecting them, is given in:

eftec (2015) Developing UK Natural Capital Accounts: Woodland Ecosystem Accounts. Report for Defra

UK National Ecosystem Assessment (2011) Technical Report

Forestry Commission (2017) Forestry Statistics 2017

Natural England (2012) Carbon storage by habitat: Review of the evidence of the impacts of management decisions and condition of carbon stores and sources. Natural England Research Report NERR043

Forestry Commission (2015) Ecosystem services and forest management

Local sources of evidence include:

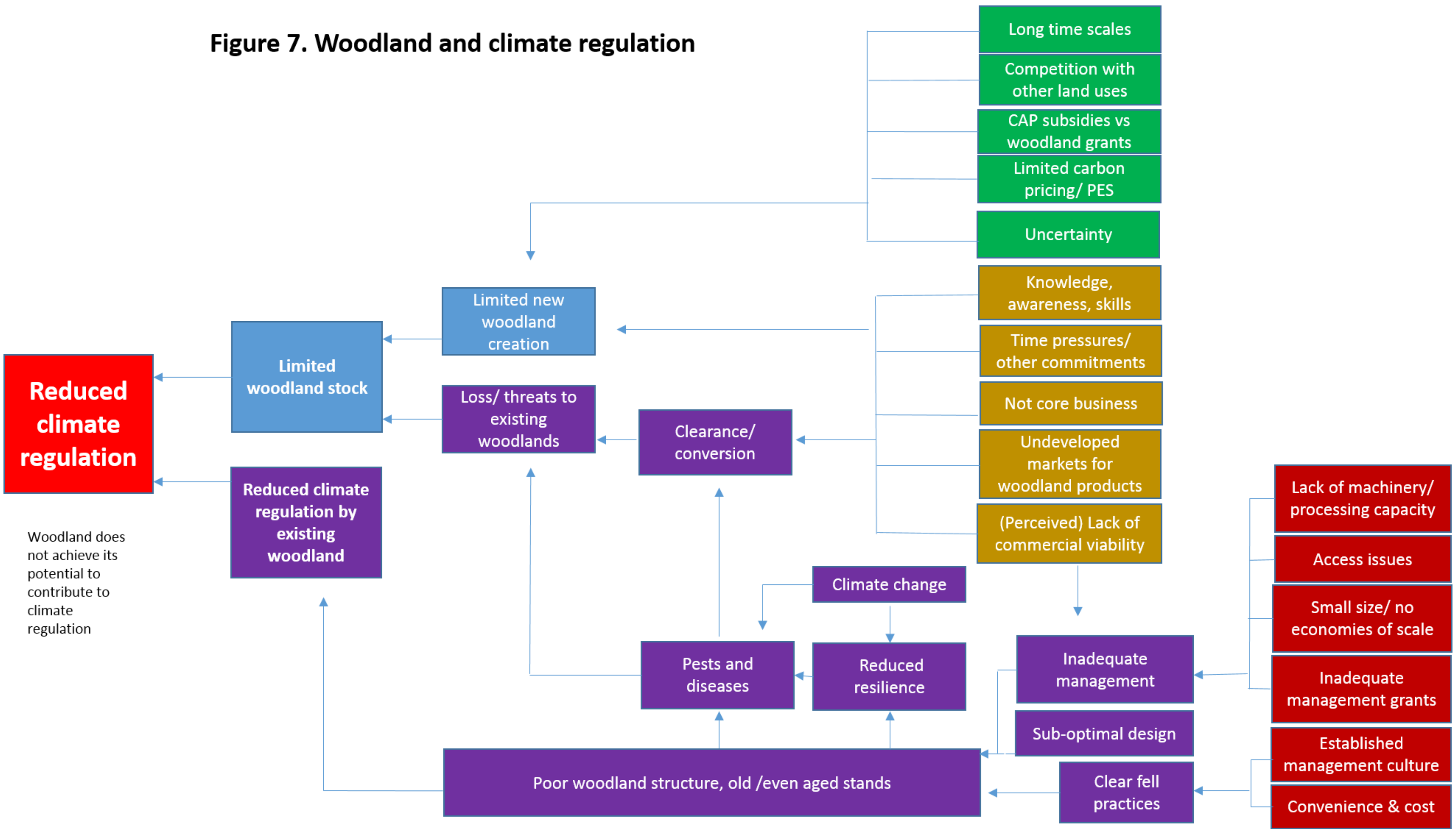
North Devon Nature Improvement Area (2015) North Devon NIA. The first three years: 2012 – 15 - Progress and learning so far.

eftec (unpublished) Assessment of natural capital in the Landscape Pioneer (North Devon). Report for Defra.

Devon Local Nature Partnership (2014) State of Devon's Nature 2013

North Devon's Biosphere Reserve (2014) The State of North Devon UNESCO World Biosphere Reserve

Figure 7. Woodland and climate regulation



8. Deciduous Woodland and Water Regulation

8.1. Deciduous Woodland and Water Regulation Services

Forests moderate rainfall, delaying and reducing flood events. Forest and tree cover can help to regulate flows from land to streams and rivers, and also affect the quality of that water. In general, benefits from increased woodland cover are likely in the uplands and upland fringes, and may not require very large changes to the land cover of whole catchments. There is likely to be some benefit from increasing tree cover in floodplains. Any increase in cover will need to be carefully planned, identifying where a slowing of water movement may be desirable, and ascertaining the possible implications of trees caught in floods blocking bridges downstream (UKNEA, 2011). Targeted planting along watercourses, and subsequent woody debris in channels upstream of vulnerable areas, can slow the flow of floodwater (POST, 2014a). Recent work on the potential impact of natural flood management in Cumbria concluded that large-scale planting of deciduous trees at key locations could significantly reduce flood peaks (Huggett, 2017).

8.2. The Problem

The ability of deciduous woodland to regulate water flows in North Devon is limited by the restricted area of deciduous woodland in the right places.

It is estimated that there are currently approximately 5,000 ha of coniferous and 30,000 ha of broadleaved woodland in North Devon; woodlands therefore account for approximately 15% of the terrestrial land area of the Biosphere Reserve (eftec, unpublished). Unlike for climate regulation services, the ability of deciduous woodland to provide water regulation services depends critically on its location (UKNEA, 2011).

In addition, the condition of existing woodlands in the area is affected by a lack of management, which is believed to limit the delivery of water regulation services.

8.3. The Causes

As for woodland and climate regulation, the causes of reduced water regulation services are linked to the limited extent of woodland in North Devon compared to agriculture, limited rates of woodland expansion, and reduced regulating services by existing woodland.

In addition, the location of woodland is important in determining its ability to regulate water flows. Evidence is lacking regarding the location of existing deciduous woodlands in North Devon with regard to their ability to deliver water regulation services. However, UKNEA (2011), POST (2014a) and Huggett (2017) highlight the location specific nature of water regulation by woodland and emphasise the importance of planning of woodland planting to optimise these services. In the absence of such planning, it would be surprising if existing woodlands were located in places where these services are maximized.

The different ways that woodland can affect flood flows are greatly influenced by design and management factors (Nisbet and Thomas, 2006). Forest design determines species, age and structural diversity, as well as the balance of forest cover and open space. Location, shape, size, age and species choice all influence the flood attenuation effect. Woodland management also exerts a marked impact on the ability of woodlands to reduce flood flows. Ground cultivation and drainage has the effect of tending to speed-up the removal of water from a site. This is greatest for deep ploughing and intensive drainage, which can increase the density of surface water channels by 60 times or more.

Felling is the most dramatic intervention with effects on both woodland water use and runoff pathways. Clearfelling usually leaves a bare site with minimal water use apart from the interception loss associated with brash residues. The increase in run-off and therefore greater contribution to flood flows is likely to last for at least 10-15 years until the replanted trees close canopy once again. Timber harvesting and extraction can have an even greater effect on flood generation. Poor practice such as the use of inappropriate machines and excessive loads can cause severe ground damage, leading to rapid run-off from compacted soil and along wheel ruts. Overall, there appears to be significant scope for using woodland to help reduce flood risk, as well as to provide a wide range of other environmental, social and economic benefits. However, in order to achieve these, woodland needs to be better integrated with agriculture and other land uses as part of a whole-catchment approach to sustainable flood management (Nisbet and Thomas, 2006).

Partners suggest that water regulation services are affected by woodland management, and that they are limited by factors such as a lack of ground flora and water retaining features, as well as shallow root systems and low levels of new woodland growth. However, local evidence on this is lacking.

The reasons for the limited extent of deciduous woodland, for low rates of new woodland planting, and for under-management of existing woodlands are set out under woodland and climate regulation (Section 7.3).

8.4. Possible Interventions

Interventions identified by partners are the same as for woodland and climate regulation (above).

8.5. The Evidence

National evidence on water regulation by deciduous woodland includes:

Nisbet T R and Thomas H (2006) The role of woodland in flood control: a landscape perspective

Parliamentary Office of Science and Technology (2014) Catchment-Wide Flood Management. POSTnote Number 484 December 2014.

Dadson SJ et al. (2017) A restatement of the natural science evidence concerning catchment-based 'natural' flood management in the UK. Proc. R. Soc. A 473: 20160706. http://dx.doi.org/10.1098/rspa.2016.0706

Huggett D (2017) Working with nature to reduce flood risk. Blog, 30 March 2017. Environment Agency.

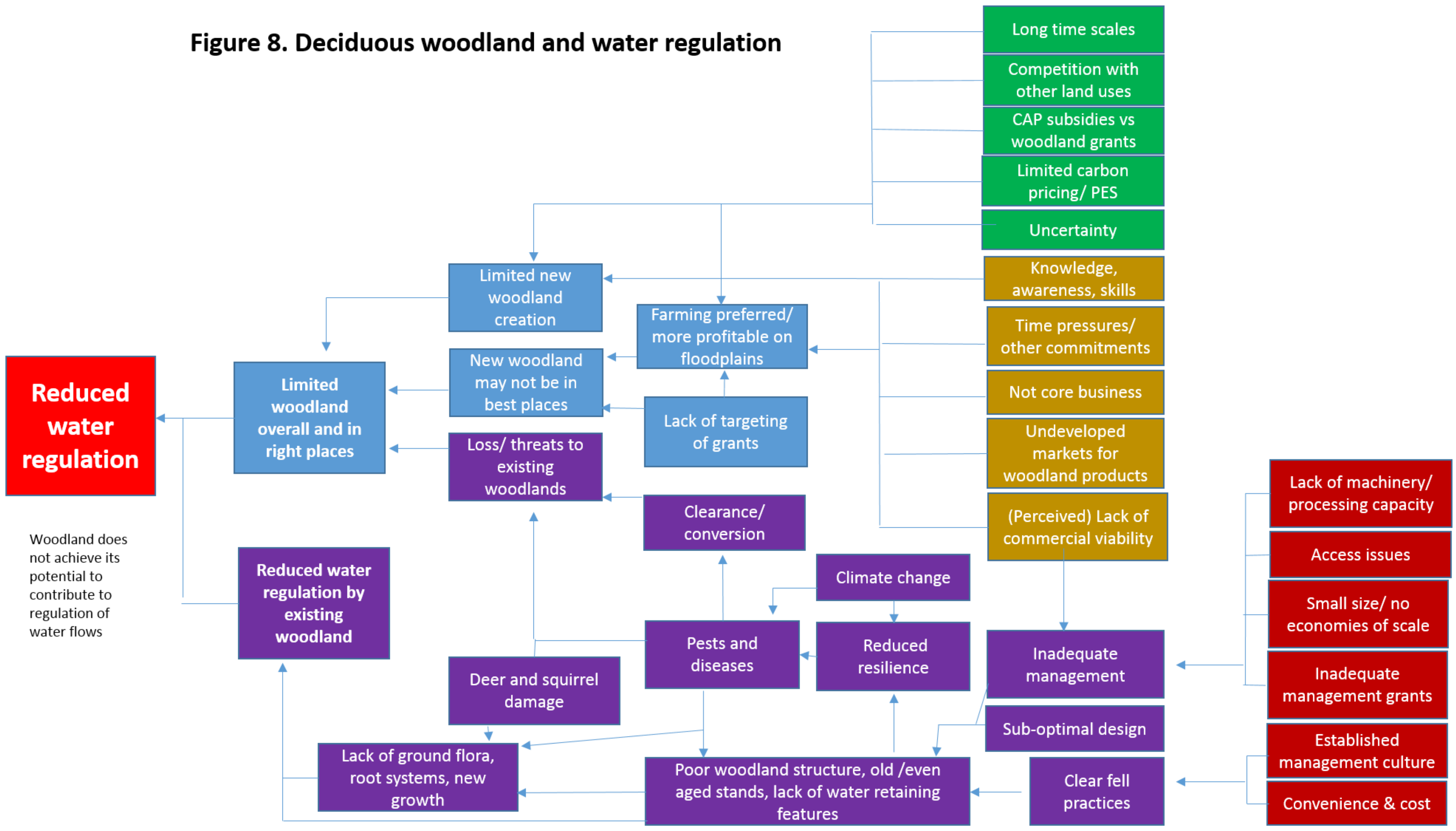
Environment Agency (2015) Cost estimation for land use and run-off – summary of evidence

Pilkington, M, Mount, D, Walker, J, Allott, T, Ashton-Waird, R, Evans, M, Hammond, G, Huggett, D, Nisbet, T, Rose, S (2015) Natural Flood Management; an appraisal of current status. Moors for the Future Partnership, Edale, Derbyshire, UK.

UK National Ecosystem Assessment (2011) Technical Report

eftec (unpublished) gives data on the extent of woodland cover in North Devon.

Figure 8. Deciduous woodland and water regulation



9. Culm Grassland, Water Regulation and other Ecosystem Services

9.1. Culm Grassland and Ecosystem Services

Culm grassland is the name given to damp unimproved grasslands that have developed above a geological formation known as the Culm Measures laid down in the Carboniferous period (about 300 million years ago) in north-west Devon and north-east Cornwall. The geology of the Culm Measures has given rise to acidic, clay soils that are poorly drained. In addition, the relatively high rainfall experienced in south-west England makes the soil very damp, circumstances that persist even through the driest of summers. The habitat is rare elsewhere in the UK, with Northern Devon containing approximately 35% of the remaining Culm grassland resource in the UK (NDNIA).

Culm grassland landscapes have the potential to store significant amounts of water as they have not been drained, unlike their intensively-managed counterparts. They also exhibit much lower runoff coefficients than intensively managed grasslands, resulting in a much more attenuated response to rainfall and a notable reduction in water rapidly entering channels immediately following storm events. They yield high water quality as they are not exposed to fertilisers, pesticides or herbicides; they store soil carbon as they are not tilled or limed to improve productivity; and support one of the ten most endangered species in the EU – the Marsh Fritillary butterfly (Puttock and Brazier, 2014). The ‘Proof of Concept’ project, a partnership between Devon Wildlife Trust and Exeter University, has measured the water holding capacity of Culm grassland compared to intensive farmland. Initial results suggest that Culm grassland is up to five times more effective than intensive grassland at holding water (NDNIA, 2015).

A study by Devon Wildlife Trust (2015) estimated the value of ecosystem services delivered by Culm grassland. It was estimated that the loss of the value of freshwater resources and carbon storage from Culm grasslands, which have been converted to intensively managed grasslands since 1900 is £9.7 million at current prices; that the work undertaken to date by Devon Wildlife Trust in the restoration of Culm grassland will have a potential benefit of £9.1 million by the time it has taken full effect; and that the current Culm area has a marginal value of £14.7 million.

9.2. The Problem

Culm grasslands have become increasingly scarce due to agricultural improvement. Some 92% of Culm grassland has been lost in the past 100 years, with 48% disappearing between 1984 and 1991 alone (North Devon NIA) report. There was a further decline by 3.5% between 1998 and 2012, largely due to abandonment and inappropriate management (State of Devon’s Nature report, 2012). Most of the remaining habitat is in small fields and designated as a Site of Special Scientific Interest and/or a Special Area of Conservation. The current area in the North Devon Biosphere reserve is approximately 4,000 ha (North Devon’s Biosphere, 2014). Devon Wildlife Trust (2017) warned that, despite significant conservation efforts, Culm grassland is still under threat, and the current habitat resource is fragmented across a landscape where farming continues to intensify.

9.3. The Causes

The chief causes of the loss of Culm grassland have been agricultural improvement of land by drainage, ploughing, reseeding and fertiliser application; afforestation; abandonment and neglect; management inappropriate for conservation purposes (e.g. over-grazing); and habitat fragmentation (North Devon NIA). Improvement for agriculture has led to the development of intensively managed grassland capable of carrying more livestock or supporting forage production for longer periods (Devon Wildlife Trust, 2015). In some cases this has allowed milk production to take the place of beef rearing. In other areas the traditional grasslands have been undergrazed or not grazed at all, allowing scrub to encroach (Devon Wildlife Trust, 2015).

Several attempts have been implemented to halt the decline including those by Devon Wildlife Trust (Culm Natural Networks and more recently the Working Wetlands and Northern Devon NIA projects), Butterfly Conservation (Reconnecting The Culm), and Natural England (through the Higher Level Stewardship Scheme) (NDNIA). A total of 3,984 ha of Culm grassland had been restored or recreated in Devon by 2015 (Devon Wildlife Trust, 2015).

NDNIA (2015) noted that often it is the lack of appropriate grazing animals, or suitable machinery, that prevents Culm grassland restoration. Support by the North Devon NIA and Working Wetlands projects reinstated favourable grazing on 76 Culm grassland sites, and improved site condition using the Devon Wildlife Trust machinery ring in 133 cases (NDNIA, 2015).

Puttock and Brazier (2014) argued that, despite their multiple benefits, Culm grasslands were forgotten, too wet to farm for high yields and offering little financial incentive to manage. In part this was due to the lack of knowledge of what Culm grasslands could provide and how they could mitigate the effects of land use and climate change upon flooding, soil erosion and diffuse pollution. Traditionally, Culm grasslands are managed by the light grazing of local cattle breeds, to promote sward re-growth and avoid scrub invasion. In many areas, woody species have colonised areas of previously open grassland, unless shrub removal management has been undertaken (Puttock and Brazier, 2014).

These changes mirror a national decline in semi-natural grassland, of which around 90% has been lost in the UK's lowlands since 1945 (UKNEA. 2011). This was driven by agricultural improvement, in turn caused by technological advances and incentives. More recently, agricultural improvement has decreased in importance as a driver, as much semi-natural grassland is now protected.

9.4. Possible Interventions

The following interventions are proposed by Pioneer partners:

CG1. Better agri-environment schemes, including higher payments. Under the current system, payment rates are based on costs incurred and income foregone. Partners argue that there is a need for higher payment rates which make full payment of costs and income foregone, based on the economics of Culm grassland management. These payments should be higher to reflect the diseconomies of scale associated with the often fragmented Culm grassland resource – achieving appropriate grazing and management schemes may often have higher costs compared to more wide-ranging habitats. Ideally, however, there should be a new payment mechanism based on payment for results, reflecting the high value of biodiversity and range of ecosystem services associated with Culm grassland.

CG2. Stronger regulatory enforcement. The EIA Regulations protect uncultivated land and semi-natural areas, including Culm grassland, from being damaged by agricultural works which increase the agricultural productivity of the land. Consent is required from Natural England before any potentially damaging works (such as application of fertiliser, cultivation, re-seeding or drainage) can occur (Natural England, 2012). However, there is concern among partners that a lack of effective enforcement is contributing to continued loss and degradation of Culm grassland habitats. In addition, enhanced enforcement of water quality legislation, including in the Nitrate Vulnerable Zone, would help to encourage lower intensity grassland management.

CG3. Management at scale. Partners argue that there would be benefits in a programme to strengthen co-operation/larger scale approaches in management of the Culm and tackle problems of fragmentation. This could include shared machinery and livestock, collaboration in scheme applications and joint provision of ecosystem services, and potentially leasing or joint management agreements over the resource. This would help to tackle problems of fragmentation – which leads to diseconomies of scale in management as well as reduced ecosystem service delivery.

CG4. Culm marketing/branding campaign. An awareness raising initiative could enhance understanding of the uniqueness, local distinctiveness and importance of Culm, strengthening "brand awareness" and local responsibility for the habitat. Partners express the view that Culm grassland is under-appreciated and that local pride in and responsibility for the habitat, and interest in protecting and restoring it, would be increased if there was greater local awareness.

CG5. Culm habitat programme. There would be benefits in a more ambitious programme for the habitat, setting ambitious targets for maintenance, restoration and creation, to be achieved through a range of other measures such as those outlined above.

CG6. Research. Further research would help to:

a. Improve understanding of the role of Culm as part of farm businesses, to inform development of farm business solutions; and

b. Improve understanding of hydrology and role of Culm in regulating water flows and quality.

9.5. The Evidence

Key sources of evidence on Culm grasslands, the services they provide and the pressures they face include:

Devon Wildlife Trust (2017) Culm Grassland Natural Flood Management Project - March 2017 Newsletter

Devon Wildlife Trust (2015) The Economic Value of Ecosystem Services Provided By Culm Grasslands

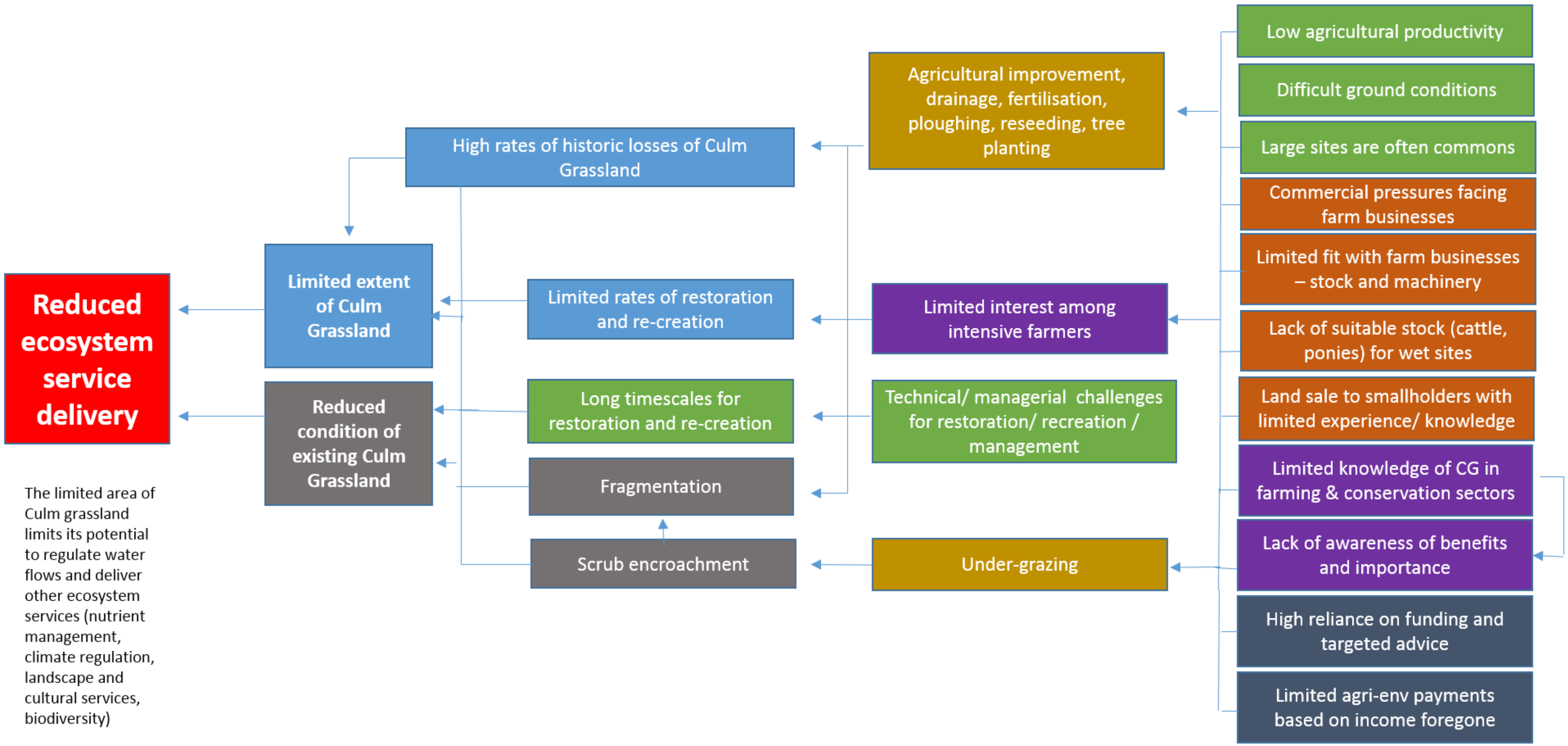
North Devon's Biosphere Reserve (2014) The State of North Devon UNESCO World Biosphere Reserve

North Devon Nature Improvement Area (2015) The first three years: 2012 – 15. Progress and learning so far

Puttock and Brazier (2014) Culm Grasslands Proof of Concept Phase 1. Developing an understanding of the hydrology, water quality and soil resources of unimproved grasslands

UK National Ecosystem Assessment (2011) Technical Report

Figure 9: Culm Grassland, Water Regulation and other Ecosystem Services



10. Analysis of Potential Interventions

10.1. Linking RCAs to potential interventions

The root cause analysis helps to highlight the different stages of the causal chain in which interventions can take place. In general, addressing the root causes of problems is likely to be more effective than dealing with their symptoms. For example, preventing the generation of wastes and pollution may be more effective and provide greater certainty than measures designed to restrict the transport of pollutants to watercourses. However, in some cases addressing root causes may be costly or infeasible, for example if it requires overall changes in land use systems.

Figure 10 illustrates this with the example of improved pasture and water quality. The impact of improved pasture on water quality may be addressed:

i. Close to the environmental receptor – for example by introducing buffer strips adjacent to watercourses to prevent or reduce the entry of pollutants.
ii. In the middle of the causal chain – for example by using winter cover crops to reduce erosion and run-off.
iii. Through interventions that may help to address the root causes of the problem. These may include education and awareness raising, to provide farmers with the knowledge needed to change their operations to avoid pollution; stricter regulatory enforcement, to require changes in behavior that prevent and avoid pollution; or, more radically, changes in the land use system to move land away from polluting activities such as dairy farming and towards lower impact land uses such as extensive livestock systems or woodland.

10.2. Interventions proposed by Pioneer partners

The Root Cause Analysis maps were used to identify potential interventions to address the environmental problems identified. Pioneer partners were invited to identify the most promising interventions for each problem, through a series of teleconferences.

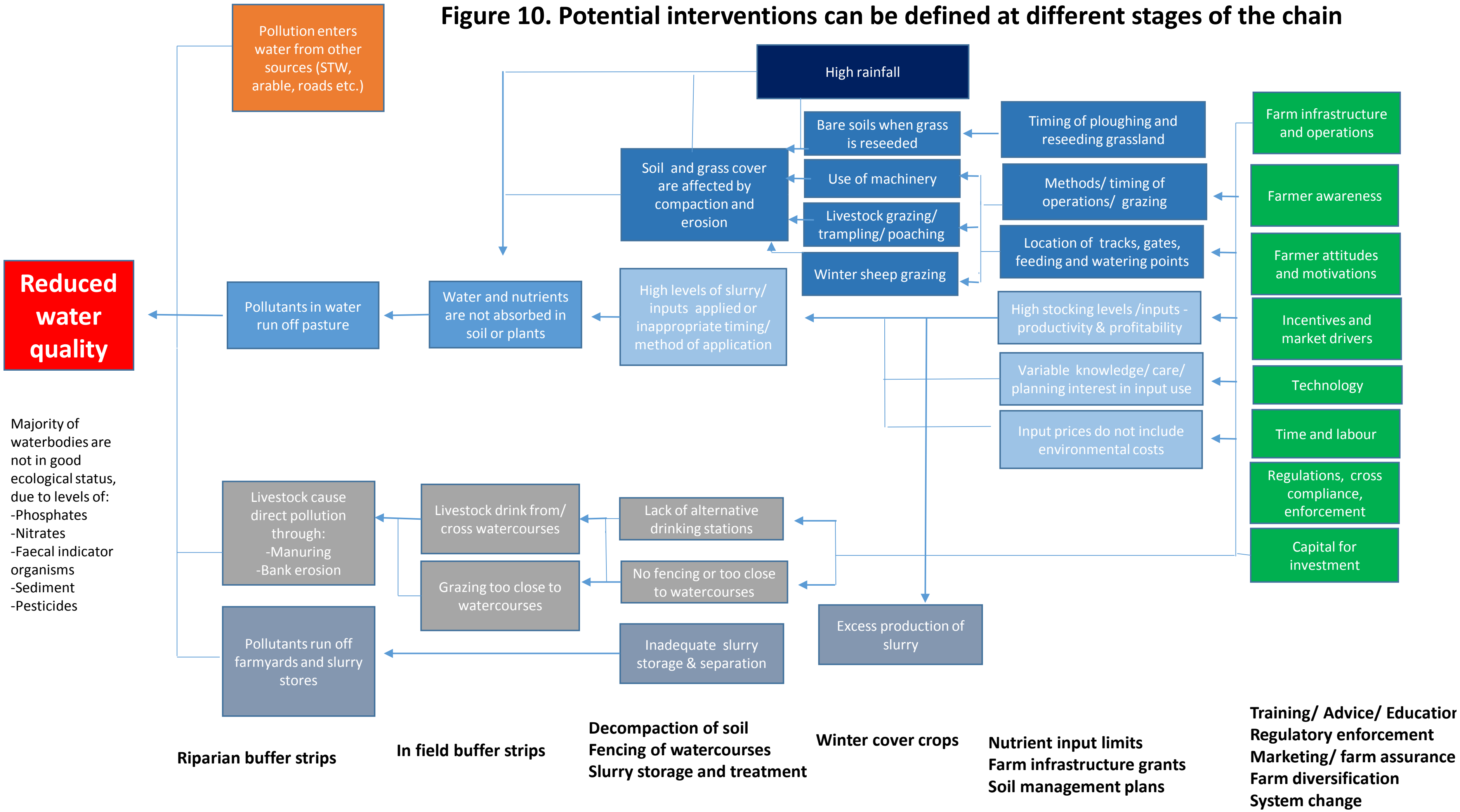
The proposed interventions are set out in the relevant sections for each RCA above. Many interventions are common to different problems. For example, more stringent enforcement of existing regulation is identified as an intervention for permanent grassland and water quality, improved pasture and water quality, arable land and water quality, improved pasture and climate regulation, and Culm grassland and ecosystem services.

In order to analyse the proposed interventions, it is helpful to group them to define a shorter list of interventions (Table 10.1).

Table 10.1: Grouped interventions

Intervention	Intervention codes in RCA text
System change away from dairy	PGW1, IPW1, IPC1
Tradeable catchment nutrient limits	PGW2, IPW2, IPC2
Farm business planning and advice	PGW3, IPW3, IPC3
Shared equipment for better soil and nutrient management	PGW4, IPW4, IPC4
New and improved agri-environment schemes	PGW5, IPW5, IPC5, CG1, AWQ5
Enhanced market assurance	PGW6, IPW6, IPC6, AWQ3
Farm diversification	PGW7, IPW7, IPC7
Better regulatory enforcement	PGW8, IPW8, IPC8, CG2, AWQ1
Soil management planning and advice	PGW9, IPW9, IPC9, AWQ2
Slurry management enforcement, grants and advice	PGW10, IPW10, IPC10
Signposting existing tools	PGW11, IPW11, IPC11
Scaling up Culm grassland management	CG3
Culm marketing campaign	CG4
Culm habitat programme	CG5
Culm research	CG6
Land use mapping	AWQ4, WES3
Tourism strategy	CMC1
Visitor payback/giving	CMC2
Managed realignment	CMC3
Biodiversity net gain initiative	CMC4
Investment in upgrading sewage infrastructure	CMC5
Codes of conduct for jet-skis and powered craft	CMC6
Traffic management measures	CMC7
Reform of agricultural subsidies	WES1
Woodland PES schemes	WES2
Woodland advice, training and marketing	WES4
Woodland co-operatives	WES5

Figure 10. Potential interventions can be defined at different stages of the chain



10.3. Criteria for assessment

The long list of interventions can be assessed against the following criteria:

- **Different from current practice in approach, scale or ambition.** The RCAs identify a range of widespread and substantial environmental problems that persist in spite of a range of interventions to address them. To address these problems, it is clear that new interventions are required, applying different approaches than those used to date, or intervening with greater scale and/or ambition;
- **As close to the root cause as feasible.** The effectiveness of interventions will be tend to be greater where they are able to address the root causes of the identified problems;
- **A positive effect on multiple ecosystem services**. Preferred interventions will enhance a range of ecosystem services rather than trading one service off against another.
- **A positive impact on natural capital asset state.** Central to the natural capital approach is that interventions seek to enhance the state of natural capital assets over time.
- **Net positive on biodiversity.** The preferred interventions should lead to overall net improvements in biodiversity, rather than increasing particular ecosystem services while reducing biodiversity overall.
- **Likely positive balance of costs and benefits**. While a full analysis of costs and benefits is not feasible at this stage, evidence should suggest that the benefits of the interventions identified are likely to exceed their costs.

10.4. Assessment against criteria

Table 10.2 locates the suggested interventions within the chain of causal effects. The interventions on the right of the table will help to address the root causes of the identified problems. These include land use system change, catchment scale limits on nutrient inputs, farm diversification, market assurance schemes, land use mapping, research, habitat creation programmes, reform of agricultural subsidies, and a tourism strategy. Many of the suggested interventions address the problems somewhere in the middle of the chain, between the root cause and the environmental effect – these include soil and slurry management measures, tourism payback/giving schemes, managed realignment, a net gain initiative, and woodland management measures. Proposed interventions that seek to manage the effects of pressures close to their impact on the environment include tourism codes of conduct and traffic management measures.

Agri-environment and regulatory measures may both address different points in the causal chain. For example, agri-environment schemes may tackle root causes by creating habitats or changing land uses; they may help to promote land management measures that improve soil and prevent pollution (such as winter stubbles and cover crops); or they may prevent pollution entering watercourses (e.g. through riparian buffer strips and fencing of watercourses). Similarly regulatory enforcement may prompt a whole farm approach to pollution prevention, or focus on the passage of pollutants to water.

Table 10.3 provides a qualitative outline assessment of the suite of proposed interventions against the assessment criteria. In general, many of the proposed options do not represent a major departure from current practice, but partners have identified a need to upscale them in order to deal with the problems identified at the scale required. These include a range of advisory/education/training, regulatory enforcement and agri-environment measures. A small number of more novel interventions have been suggested, including dairy system change, tradeable nutrient permits, and a visitor giving scheme. The first two have the potential to have greater environmental benefits, but also with potentially high costs to the farming sector.

Table 10.2: Locating potential interventions in the causal chain of effects

Interventions addressing problems close to ecosystem impact	Interventions addressing problems towards middle of chain of effects	Interventions addressing problems close to root cause
	Shared equipment for soil management	Land use system change
	Soil management planning and advice	Tradeable catchment nutrient limits
	Slurry storage and treatment	Farm and woodland business planning, advice, training
	Slurry management advice and planning	Farm diversification
		Market assurance schemes
		Scaling up Culm management
		Culm marketing campaign
		Culm habitat programme
		Culm research
		Land use mapping
	Agri-environment measures:	
Riparian buffer strips Fencing of watercourses	In-field buffer strips Winter cover crops	Habitat creation
	Stricter regulatory enforcement – may address different stages in the causal chain	
Codes of conduct for powered craft	Tourism payback/ giving	Tourism strategy
Traffic management	Managed realignment	
	Net gain initiative	
	Investment in sewerage infrastructure	
		Reform of agricultural subsidies
		Woodland collaboration scheme
	Enhanced woodland management grants	Enhanced woodland creation grants

Table 10.3: Initial qualitative assessment of proposed interventions against criteria

Intervention	Different from current practice	Close to root cause	+ve effect on ecosystem services	+ve effect on natural capital assets	+ve effect on biodiversity	Cost	Benefit
System change away from dairy	***	***	***	***	**	High	High
Tradeable catchment nutrient limits	***	**	**	**	*	Medium	Medium/ High
Farm business planning and advice	*	**	*	*	*	Low/Medium	Low/Medium
Shared equipment for better soil and nutrient management	*	*	**	**	*	Low	Low/Medium
New and improved agri-environment schemes	**	**	**	**	**	Medium	Medium/High
Enhanced market assurance	*	**	*	*	*	Low	Low/Medium
Farm diversification	*	***	*	*	*	Low/Medium	Low/Medium
Stricter regulatory enforcement	**	**	**	**	**	Medium	Medium/High
Soil management planning and advice	*	**	*	*	*	Low/ Medium	Low/Medium
Slurry management enforcement, grants and advice	*	**	**	**	*	Medium	Medium
Signposting existing tools	*	**	*	*	*	Very Low	Low
Scaling up Culm grassland management	**	**	**	**	**	Low/Medium	Low/Medium
Culm marketing campaign	**	**	*	*	**	Low	Low/Medium
Culm habitat programme	**	**	**	**	**	Low/Medium	Low/Medium
Culm research	-	**	*	*	*	Low	Low
Land use mapping	**	***	*	*	*	Low	Low/Medium

Intervention	Different from current practice	Close to root cause	+ve effect on ecosystem services	+ve effect on natural capital assets	+ve effect on biodiversity	Cost	Benefit
Tourism strategy	**	**	*	*	*	Low	Low/Medium
Visitor payback/giving	***	**	*	*	*	Low/Medium	Low/Medium
Managed realignment	**	**	***	***	***	Medium/High	High
Biodiversity net gain initiative	**	**	**	**	***	Medium	Medium
Investment in upgrading sewage infrastructure	-	***	**	**	*	Medium	Medium/High
Codes of conduct for jet-skis and powered craft	*	*	**	*	**	Low	Low
Traffic management measures	**	*	*	*	-	Low/Medium	Low/Medium
Reform of agricultural subsidies	**	***	**	**	**	Low/Medium	Medium/High
Woodland PES schemes	**	**	***	***	***	Medium	Medium/High
Woodland advice, training and marketing	*	**	*	*	*	Low/Medium	Low/Medium
Woodland co-operatives	**	**	*	*	*	Low	Low

*Key: * are given for score against each criterion: * low, ** medium, *** high*
Approximate scale of costs and benefits: Low < £1 million; Medium £1-10 million; High > £10 million over next 10 years. The net value of costs depends on potential cost savings – for example reform of agricultural subsidies or savings in investment in flood defences could reduce net costs significantly.

10.5. Costs and benefits of proposed interventions

Table 10.4 identifies the type and range of costs and benefits likely to arise from each intervention, and gives an outline qualitative assessment of the potential balance of these costs and benefits.

Table 10.4: Overview of possible costs and benefits of interventions

Intervention	Costs	Benefits	Balance of costs and benefits
System change away from dairy	Lost income to farmers Reduced food output Reduced land prices Potential public spending on compensation payments	Enhanced water quality Enhanced soil structure Enhanced climate regulation Enhanced biodiversity	A wide-scale or targeted change away from dairy farming and towards low intensity grassland, woodland and other habitats would benefit biodiversity, water quality, soils and climate, with significant enhancement of ecosystem services and reductions in environmental costs. However, there would be significant costs through lost farm output and incomes. The net effect of these changes would need to be assessed.
Tradeable catchment nutrient limits	Loss of agricultural production from lower inputs Costs to farmers required to buy permits from others Overall reduction in net farm incomes Administrative and enforcement costs	Enhanced water quality More efficient use of inputs Enhanced incomes from farmers able to sell permits	Offers an opportunity to reduce nutrient inputs in line with the carrying capacity of the water environment, while encouraging efficient use of inputs within those limits. Environmental costs of water pollution are large – balance of benefits and costs depends on scale of these compared to reduced farm incomes. Administrative, compliance and enforcement costs likely to be substantial.
Farm business planning and advice	Costs to authorities/ taxpayers in providing free or subsidised advice	Benefits to environment Benefits to farm businesses in adopting more efficient and sustainable practices, reducing costs and enhancing soil/ natural capital assets	Potentially net benefits through win-wins for farm businesses and the environment, unlocking efficiency gains. However, depends on addressing barriers to uptake and engaging farmers who have most to gain. Experience may suggest that net gains do not come easily.
Shared equipment for better soil and nutrient management	Costs to authorities in subsidising and/ or co-ordinating provision of shared equipment	Benefits to environment Benefits to soil and natural capital assets Cost savings of shared equipment	Potential for win-wins for environment and farm businesses; these need to be compared to costs of public sector support, including administrative and transactions costs
New and improved agri-environment schemes	Costs to authorities in providing agri-environment payments Administrative and monitoring costs for authorities and farmers Potential loss of net incomes if increased at expense of basic payment	Benefits to environment New schemes and payment mechanisms could enhance benefits by incentivising ecosystem service provision Support other parts of diversified farm businesses	Previous studies indicate positive net benefits but high running costs of agri-environment schemes
Enhanced market assurance	Administrative, monitoring and enforcement costs for farmers and buyers Compliance costs for farmers associated with higher standards	Benefits to environment through improved practices Benefits to farm incomes from premium prices	Offers potential for an efficient, market-based solution to environmental problems caused by agriculture Environmental benefits depend on public willingness to pay for enhanced standards, willingness and ability of food sector to enforce these Farmers would need to weigh up benefits of entry with costs of compliance and administration Farm assurance schemes already exist and potential to use them to address specific local problems is unclear
Farm diversification	Costs for farmers of investing in farm business diversification schemes	Benefits for farm business Environmental benefits through reduced pressure to intensify production,	Environmental benefits are uncertain and indirect Not all farmers have opportunity to diversify

	Costs of public support through rural development schemes	enhanced incentive to seek synergies through environmentally beneficial management practices	Questionable efficiency/added value of support for diversification; if benefits to farm business exceed costs, farmers might already be diversifying; case for support would need to be made on basis that benefits need to be unlocked
Stricter regulatory enforcement	Costs to farmers of compliance, investment in waste storage and pollution control, income foregone from reduced input use Costs to authorities of monitoring and enforcement	Benefits to environment from reduced pollution Enhanced ecosystem services associated with water environment Benefits to farm business through more efficient input use	Regulations are introduced on the basis that benefits exceed costs, but net benefits depend on effective enforcement
Soil management planning and advice	Administrative and time costs for farmers and authorities in soil planning and management	Enhanced benefits to farm business through improvements in soil Benefits to environment through reduced erosion and pollution	Investing in soil management is good farm business practice and should yield net business benefits; however, some farmers are harder to convince than others and expanding schemes may not necessarily deliver results; knowledge gaps can also be a barrier to progress
Slurry management enforcement, grants and advice	High capital costs to farmers of investing in slurry storage and treatment Costs to authorities of enforcing existing rules	Environmental benefits through better slurry management and reduced pollution. Enhanced water quality and climate regulation Benefits to soil, and hence farm businesses, of better slurry management	Slurry is a major cause of water pollution and greenhouse gas emissions in North Devon, and enhanced storage and management of slurry will have substantial benefits to the environment as well as for farm businesses. The capital costs of slurry storage and treatment are substantial, but often required to meet existing regulatory commitments.
Signposting existing tools	Costs to Pioneer partners in signposting existing tools, guidance and incentives	Benefits of greater awareness and uptake of existing schemes and measures	Making the most of existing information, guidance and schemes is important before delivering new interventions; this is a low cost measure.
Scaling up Culm grassland management	Time, administrative and financial costs to public sector and farmers of co-ordinating management, organising joint entry into agri-environment schemes, providing shared equipment and livestock	Benefits and cost savings from enhanced economies of scale in management of Culm Environmental benefits of better management of Culm grassland	Financial costs are relatively low compared to potential benefits; however time required and associated administrative costs may be significant relative to scale of action
Culm marketing campaign	Costs to public sector of an information/ marketing/ branding campaign	Benefits of increased awareness, pride, ownership of Culm grassland among local community	Costs are relatively low; benefits could be significant but are intangible, uncertain and difficult to assess
Culm habitat programme	Time and administrative costs in determining objectives and targets and defining actions Costs for agri-environment programme in delivering the defined programme of activity	Benefits for biodiversity and multiple ecosystem services delivered by Culm	Local evidence suggests the high value of benefits of Culm grassland (including carbon, water regulation and biodiversity values) relative to the costs of management, restoration and re-creation
Culm research	Costs of commissioning and undertaking research	Enhanced understanding of management needs and benefits of Culm, helping to enhance effectiveness and efficiency of management strategies	Costs are relatively small; benefits are uncertain and less tangible but potentially outweigh costs
Land use mapping	Costs of staff time and data required for land use mapping	Mapping optimal land use across North Devon should help to guide more effective and efficient land use decisions, potentially helping to optimise the management of natural capital and the delivery of ecosystem services	Costs are relatively low; benefits potentially greatly outweigh the costs by optimising land use decisions, enhancing natural capital and ecosystem service delivery, and addressing environmental problems; however, realising these potential benefits would depend on being able to use information from mapping to change land use decisions

Tourism strategy	Time of authorities and private sector partners in developing strategy; costs of measures required to implement the strategy, including potentially capital investments as well as information, decision-making and other costs	Potential benefits to tourism sector and environment in enhancing value of the tourism economy and reducing environmental impacts relative to numbers of visitors	Aim would be to develop a tourism economy that delivers higher economic benefits at lower environmental costs – hence potential "win-win". Uncertainty of whether this is achievable and whether the chances of success justify the time and effort involved. Requires a shared vision and co-ordinated action among local private and public sector partners.
Visitor payback/giving	Cost to visitors asked to contribute to local environmental projects (likely to be voluntary) Cost to tourism operators and authorities in administering scheme	Benefits to environment from funding local environmental projects Benefits from enhanced connection between visitors and local environment	Voluntary nature of scheme should limit any adverse economic impact; benefits may be relatively small in scale; potential for administrative and transaction costs to be relatively high compared to funding raised; however, there could be additional intangible benefits from increasing awareness and connection between visitors and local environment
Managed realignment	Capital costs and potentially opportunity costs from managed realignment schemes, depending on condition of current flood defences; also significant time and transactions costs	Substantial environmental benefits through creation of coastal habitats, reducing coastal squeeze, maintaining ecosystem services	Likely to be high costs and high benefits compared to other interventions; balance of costs and benefits depends on choice of appropriate sites
Biodiversity net gain initiative	Costs to developers of providing biodiversity offsets Administrative and transactions costs for planners and private sector	Benefits to natural environment and ecosystem services through habitat creation and restoration; net gain in biodiversity and ecosystem services	A well run net gain scheme should ensure that the benefits exceed the costs
Investment in upgrading sewage infrastructure	High capital costs	Benefits through enhanced river water and bathing water quality and associated ecosystem services	Investments need to be targeted through SWW capital investment programme to ensure benefits outweigh costs
Codes of conduct for jet-skis and powered craft	Low costs of developing codes of conduct; costs of monitoring and enforcement are potentially higher; cost effective solutions may depend on co-operation of appropriate personnel (e.g. car parking attendants)	Benefits through reduced disturbance of species, habitats, improved tranquillity and visitor experience	Benefits will exceed costs providing appropriate compromises can be found, and subject to goodwill and co-operation of tourism sector and visitors
Traffic management measures	Costs to public sector of studies, provision of traffic management schemes (e.g. park and ride) Potential costs through time and inconvenience of compliance by visitors	Benefits through reduced congestion, noise, pollution; improved visitor experience	Further evidence needed about extent of problems and costs and benefits of potential solutions
Reform of agricultural subsidies	Scale of current expenditure means that reforms likely to be cost neutral or positive for public budgets Potential loss of farm incomes and adverse effects on land values through reform of basic payments	Potential environmental benefits through increased competitiveness of and finance for woodland and habitat creation schemes	Focusing public money on public goods offers potential for substantial net benefits
Woodland PES schemes	Costs to public authorities and/or private sector in planning, providing administering payments for ecosystem services	Benefits to environment and delivery of ecosystem services	Benefits should exceed costs for successful schemes; however, significant uncertainties and co-ordination problems are a barrier to developing and delivering PES

Woodland advice, training and marketing	Costs to authorities of provision of advice and training	Benefits to woodland owners, managers and environment through enhanced woodland management	Benefit: cost ratio is uncertain and depends on ability to address challenges of managing woodlands profitably and sustainably, and to unlock the potential of undermanaged woodlands
Woodland co-operatives	Transactions and administration costs to authorities and woodland owners in achieving cooperative management and marketing; financial costs of joint advice/ support/ investment in machinery	Benefits to woodland owners, managers and environment through enhanced woodland management	Benefit: cost ratio is uncertain and depends on ability to address challenges of managing woodlands profitably and sustainably, and to unlock the potential of undermanaged woodlands

11. Conclusions and Recommendations

11.1. Overview

This report documents the application of Root Cause Analysis (RCA) to eight problems affecting ecosystems and their services in North Devon. The RCA has enabled the chain of causes and effects to be mapped and evidenced for each problem, and potential interventions to be identified and analysed.

11.2. Reflections on the root cause analysis approach

Root cause analysis has previously been applied in addressing a range of problems in different fields, such as process engineering, health and safety and quality management, but there are few examples in the literature of its application to environmental problems, at least in the way described in this report.

However, the examples demonstrate that RCA can readily be used to examine the causes and pathways of problems affecting the natural environment. In general the Pioneer partners found the approach intuitive and engaged in it readily.

The RCA approach helps to identify and assess the range of potential interventions that can be applied to address natural environment problems, locating them at different stages in the chain of causes and effects. It therefore helps to highlight those types of intervention which address the root causes of the problems identified, and those that deal with the symptoms and environmental effects.

The exercise has helped to highlight a small number of potential interventions that would represent a significant change to current actions taken to improve the natural environment in North Devon, and many more that involve building on or upscaling current practice. This is perhaps unsurprising, and it is difficult to tell whether the exercise has encouraged new thinking, or merely helped to illustrate existing practice and ideas. Nonetheless, it is hoped that the RCA provides a helpful conceptual framework which can be used to inform further analysis of potential interventions to address the ecosystem problems assessed.

11.3. Recommendations for future work

Future work could:

- Further refine the evidence base for each RCA;
- Prioritise the potential interventions identified, building on the analysis above to select a smaller number of interventions to be specified, developed and assessed in greater detail;
- Specify the most promising interventions further, setting out the scale and nature of action required, the actors involved, resources required, timetable and measures of success;
- Further analyse and quantify the likely costs and benefits of each priority intervention.

It is hoped that the Pioneer partners will continue to engage in this work and to take forward the interventions proposed to date. A further workshop is planned for this purpose.

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