CREW CENTRE OF EXPERTISE FOR WATERS

A state of knowledge overview of identified pathways of diffuse pollutants to the water environment

Executive Summary

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Research questions

The overall aim of the project is to provide a state of knowledge overview on pathways of diffuse pollution from agriculture to the water environment and to produce Knowledge Exchange (KE) products that will help address these issues. This report addresses the former, answering questions posed around scale and extent, solutions, costs, impacts and gaps in knowledge and these will help inform the KE products.

Background

The River Basin Management Plans for the Scotland and the Solway Tweed river basin districts set out Scotland's ambition to improve from 62% of waterbodies in Scotland at good status to 88% by 2027, and 93% in the longer term. Tackling rural diffuse pollution is key to achieving these aims. The primary focus of Scotland's strategy to tackling diffuse pollution is centred on achieving compliance with the diffuse pollution General Binding Rules, Nitrate Vulnerable Zones, promoting good practice and encouraging uptake of additional measures through funding schemes such as the Scotland Rural Development Programme. While this effort has significantly improved compliance and good practice, it will not be sufficient to achieve good status in all catchments. We therefore need to better understand where the gaps are, particularly regarding important pathways i.e., how pollutants are transferred from land to water and what practical measures are required to help fill these gaps to help Scotland achieve water quality objectives.

Research undertaken

Focussing on the pollutants phosphorus (P) and nitrogen (N), a systematic review of existing information and evidence was undertaken of the current scientific understanding of runoff and erosion diffuse pollution pathways. The following pathways of diffuse pollution were investigated: i) **surface runoff and soil erosion, exacerbated by soil compaction and structural degradation** ii) **tramlines**, iii) **leaching,** iv) **drain-flow** and v) **hotspots**. Gathering evidence for each of these pathways, the following areas were investigated: a) **scale and extent of the problem**, b) **practical preventative measures** and **solutions to prevent or minimise losses of potential pollutants**, c) **costs associated with identified preventative measures and solutions**, d) **impacts on water quality if solutions were put in place** and e) **knowledge gaps and recommendations for future research**. Also included is a review of evidence of the use of Visual Evaluation of Soil Structure (VESS) scores for assessing drivers of diffuse pollution under different scenarios. This report summarises the overall findings from relevant applied scientific literature, practical guidance publications that are available to farmers and other appropriate supporting evidence.

Key findings

- Agricultural diffuse pollution into water bodies is a significant environmental issue.
- Good soil nutrient management such as the use of a fertiliser plan linked to soil sampling for nutrient status and soil pH is important.
- Standard agricultural practices are the main source of N and P pollution rather than poor nutrient management practices in Scotland.
- Surface runoff and erosion are the principal source of P loss in cultivated, drier soils while P loss through drains is the dominant pathway in improved grasslands on wetter soils.

Pathways of diffuse pollution:

- Soil type, climate, landscape characteristics and land management contribute to diffuse N and P water pollution.
- Arable soils in England showed that tramlines represented the dominant pathway for surface runoff and transport of sediment, N and P from cereal crops. This is also likely to be the case for Scotland.
- Drains provide a pathway for the delivery of sediment and N and P to surface waters but the dominant pathway of diffuse pollution is through erosion and sediment transport. This erosion and sediment transport is increased and exacerbated by damage to soil structure.
- One of the key causes of poor soil structure is compaction caused by trafficking along tramlines, therefore structural degradation and tramlines contribute to losses of N and P from Scottish agricultural soils.
- Reducing traffic when the soil is close to field capacity (i.e., water held in the soil after excess water has drained away) would reduce the potential for compaction, this can be achieved by considering the timing of operations.
- Use of controlled traffic farming (CTF) has been shown to improve 'untrafficked' soil structure and water movement and storage in Scotland but tramlines (which are necessary for CTF) are a dominant pathway of diffuse pollution.

- Alleviation of topsoil and subsoil compaction is recommended, with ploughing for arable crops as well as amendment of the soil through increased organic matter, tied ridging with potatoes and surface spiking and sward lifting in grasslands.
- Alleviation of subsoil compaction is more costly and difficult.
- Reduction of tramlines and aligning them across the slope, reduced or no tillage, spreading machinery loads as evenly as possible over a larger tyre diameter, use of correctly inflated very flexible tyres, delaying of tramline establishment and use of buffer strips (including novel 3D buffers) all can reduce the effect of tramlines on pollutant and sediment transport.
- The use of either very flexible tyres, or tramline disruption using a spiked harrow, has been shown to significantly decrease losses of sediment, N and P from Scottish soils under winter sown combinable crops.
- Up and down tramlines were shown to increase surface runoff from Scottish soils by around 50% compared to untrafficked or ploughed areas.
- Improvements in water quality were shown for a range of vulnerable English soils after the use of the following mitigation options: tramline disruption, minimum tillage, crop residue incorporation, contour cultivation and beetle banks.
- Conservation tillage systems are beneficial to soil and water quality but choice of tillage system should be flexible depending on specific conditions such as soil surface and structural conditions before crop establishment, preceding crop and amount and decomposition status of plant residues.
- The use of rotations, cover crops and CTF offer opportunities to realize the full benefits of no-till.
- Reducing the source of nutrient loss by employing nutrient management plans, growing suitable crops for the soil type, retention of stubble, contour farming and controlling the out-flow of field drains before they reach a water course need to be considered.
- Use of Nitrate Vulnerable Zones, control of cultivation and animal movements close to water courses help control N leaching but further research is needed to address P leaching.

Relative contribution and spatial distribution:

- An index of land use intensity (LUI) was developed to identify the spatial distribution of management and cultivation practices to assess management impacts on diffuse pollution risk.
- P loss due to runoff and soil erosion across Scotland has been estimated for combined soil erosion and LUI classes.
- P leaching to drains was greater than P loss due to runoff and soil erosion for 55% of agricultural land likely to have been drained.
- P leaching to drains was the most important pathway of P diffuse pollution in permanent grasslands (74% of total grassland area), but runoff and soil erosion contributed more to P diffuse pollution in 84% of the area covered by root vegetables.
- For P loss from arable land with cereals, relative pathway importance was slightly greater for runoff and soil erosion than for leaching to drains.
- Use of Visual Evaluation of Soil Structure (VESS) - topsoil VESS and subsoil subVESS tools can be used to assess the structural damage of soils and their susceptibility to erosion and nutrient loss.
- Agreement between VESS assessments and compaction risk mapping in Scotland.
- VESS and subVESS scores of 3 need to be monitored to ensure no further deterioration of soil structure.
- VESS and subVESS scores of 4 and 5 require direct intervention to restore soil structure and prevent potential erosion or nutrient losses.
- Greater topsoil physical degradation after harvest of potatoes and carrots.

Recommendations and knowledge gaps

- This review highlighted that effective land drainage and nutrient management is a fundamental part of modern agriculture but currently evidence of the relationships between specific Scottish agricultural drainage systems that contribute to diffuse pollution as well as the location, condition, functioning and flow volumes of these artificial drain systems is limited.
- More research is needed across all pathways. There are also many other knowledge gaps, particularly being able to identify diffuse pollution 'hot spots' in fields within Scottish catchments and our understanding of the impacts of recommended mitigation measures on water quality (as well as gathering more evidence linking VESS scores with water quality degradation).
- There is still uncertainty in erosion rates for soil and land use combinations, in particular, the erosion rate for grasslands is likely to be overestimated.
- It is recommended that future research efforts focus on gathering further evidence for the effectiveness

of practical diffuse pollution mitigation measures. All measures that have been investigated provide reduced diffuse pollution benefits with cost of implementation being the only potential drawback. More novel measures such as improved drainage design, alternative tramline and wheelings management options and 3D buffer strips should be tested further.

- Further research should be directed towards understanding and comparing the proportion of diffuse pollutants attributed to leaching, soil and particle erosion and surface runoff, particularly connectivity between source and waterbody.
- This review has found that all mitigation measures researched offer reductions in diffuse pollution. Overall, encouraging more farmers and land managers to use recommended practical mitigation measures identified here (focussing on pathways identified as being most important) is essential and indeed this is one of the next tasks within this CREW-funded diffuse pollution project.
- Based on this review, there is insufficient research or scientific understanding of mitigation measures such as compaction remediation, tramline and wheelings management, drainage management and treatment methods to definitively identify the methods that would have a cost effective or environmentally positive impact in **all situations and all Scottish soil types and climate**. However, useful UK-relevant research that has been conducted, such as detailed field investigations in England, appears to show that the measures outlined in this report can make a difference.
- Many of the most cost effective and high-level reduction practical measures identified are already included in environmental legislation (i.e., 2 m safe working distance from waterways, fertiliser application timings) but additional measures such as compaction remediation, tramline and wheelings management, drainage design/management and treatment methods need to be promoted more widely in the future to help meet water quality targets.