Research Report

Planting trees to protect water

The role of trees and woods on farms in managing water quality and quantity

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Planting trees to protect water

How integrating trees into farming systems can improve water quality and help mitigate flooding, while also supporting production.

Contents

Eden Rivers Trust

Planting trees in Cumbria to help improve water quality.

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Front cover: Farming by the River Stour. Istock/Charlie Bishop

Why is farming important to water management?

Land use has a significant impact on water quality and flooding. Agriculture accounts for around 73 per cent of all land in the UK. As the major land use it is a significant source of water pollutants, but also provides opportunities for mitigating measures. Farming practice and the configuration of farms can also affect flood risk.

Pollution can include 'point source' pollution from yards or manure heaps and slurry lagoons, through accidental spillage of chemicals, from access points for livestock to water courses and so on. It can also be through more 'diffuse' pollution through application of agricultural chemicals and manures, deposition of airborne pollutants, particularly from livestock production, or from overland runoff. An estimated 25 per cent of the phosphates and 50 per cent of nitrates in rivers are from agricultural sources.

Faecal indicator organisms (FIO) such as E.coli , associated with manures, can also contaminate water supplies. Timing and type of cultivations, crop selection, siting of cattle feeders and water troughs, and location of manure heaps, can all affect the likelihood of runoff and contamination of water courses.

Developments in agriculture over the last 50 years, such as increase in field size, loss of hedgerows and use of heavier machinery have increased the risk of soil erosion. Climate change and predicted increase in frequency of severe weather events is likely to magnify the impact of erosion (DEFRA, 2009).

Erosion leads to sedimentation and contamination of streams, rivers and other water bodies, damaging fisheries and wildlife, and increasing water treatment costs. Sediment deposits can increase the turbidity of water bodies and settle in spawning beds affecting valuable fisheries. In some cases sediment deposits can increase the risk of flooding.

On vulnerable soils, especially peats and sandy soils, wind erosion can lead to loss of topsoil, and cause damage to ditches and water courses. Drier parts of the country in Yorkshire, East Midlands and East Anglia are particularly susceptible; the increased frequency of dry summers is likely to exacerbate the problem.

Geograph/Dona Robbins

Farming can be a significant source of water pollutants, while land use can have a major impact on flood risk.

Geograph/Dr Richard Smith

Water erosion and associated nutrient loss can have a severe effect on farming businesses. Up to 2.2 million tonnes are eroded annually in the UK.

A cost to the farm

In addition to damaging water quality, soil erosion and nutrient loss are a cost to the farming business. Around 2.2 million tonnes of topsoil are eroded annually in the UK.

Erosion can reduce the long term fertility of the soil by removing nutrient rich top soil and organic matter, and can affect water infiltration and increase runoff. In the short term erosion can lead to loss of seeds, fertilisers and pesticides and incur costs associated with repeat operations (Kort et al, 1998).

Geograph/Dr Richard Smith

Surface water run-off damages soils.

Legal and policy framework

EU Water framework directive

Within Europe, the Water Framework Directive (WFD) provides overarching legislation aimed at maintaining and improving water quality. The WFD became part of UK law in 2003. It places a responsibility for applying the regulations and policies to deliver the WFD in England and Wales on the Environment Agency (EA), and in Scotland on the Scottish Environmental Protection Agency (SEPA). They work in partnership with stakeholders, including farmers and landowners, to deliver the Directive's aims.

The WFD covers not just what happens within water bodies, but also the land use surrounding them and affecting water quality. River basin management plans have been published for all river basins, describing current condition and a programme of measures to deliver environmental improvements.

There are other directives designed to improve water quality such as the bathing water directive, drinking water directive, sewage sludge directive, integrated pollution prevention control directive (Environment Agency, not dated).

Nitrate Vulnerable Zones (NVZs)

NVZs are intended to reduce agricultural pollution from nitrates. Farmers in NVZs are required to implement action plans that reduce nutrient applications (Johnson et al., 2007).

Catchment sensitive farming

Catchment Sensitive Farming (CSF) provides solutions and advice to farmers to enable them to reduce diffuse water pollution and meet water framework directives (Natural England, not dated).

Geograph/Dave Spicer

Cattle feeders should be sited at least 10m from any water body. Similarly runoff from yards discharging directly into ditches and streams should be intercepted and stored for treatment.

Tackling pollution sources

Clearly, reducing the source of pollution should form the starting point in improving water quality. This will include for instance, timing of application of manures and fertilisers to reduce losses through runoff; the timing and nature of ground cultivations can also help reduce the risk of soil erosion and sedimentation. In vulnerable areas, windbreaks reduce the risk of wind erosion of soil damaging water courses.

Careful consideration of the position of gateways, cattle feeders, water troughs and other areas where livestock congregate will reduce the risk of direct contamination of water bodies. These areas can be subject to poaching and concentrations of manure, which then leads to runoff of sediment, nutrients and organic matter. For further advice on best practice see 'What's in it for you... profit from a good environment. Farming best practice' (Environment Agency, 2008)

In water bodies, enrichment with high concentrations of nutrients, especially phosphates and nitrates, leads to eutrophication; excessive growth of algae which, as it dies and decomposes, leads to the decomposing organisms depleting the water of available oxygen, causing the death of fish and other wildlife.

Under particular environmental conditions, the decay of algal blooms can lead to a build up of bacteria which can release toxins that directly affect fish and lead to mass mortalities (DEFRA, 2008).

Adherence to regulation and advice on storage, application and disposal of pesticides reduces the risk of accidental spill or spray drift, both potential sources of water pollution. (Heath and Safety executive, undated)

Point source pollution

Point source pollution is the direct discharge of pollutants into water courses. In many cases point source pollution from agriculture can be remedied by simply removing the pollution source. For instance cattle feeder sited adjacent to water courses provide a point source of faecal contamination, and can be addressed by better siting of feeders.

Diffuse pollution

Diffuse pollution represents the movement via a range of pollution pathways, to water bodies. Diffuse pollution from agriculture is a major cause of failure of river catchments under the WFD, in particular nitrogen and phosphate pollution as a result of leaching of agricultural fertilisers. This includes losses from both organic manures and inorganic fertilisers. Such a loss represents a cost both to the farm, and to water quality.

Photoshot/Ian Murray

Eutrophication in drainage ditch Hollesley, Suffolk, England.

Pollutants

Nitrates

Pollution of water courses by nitrogen, as nitrates, arises from the application of organic manures and inorganic fertilisers to pasture and arable land. Nitrogen losses from agricultural land are estimated to account for over half of nitrogen entering surface waters (DEFRA 2004).

Nitrate is highly soluble and is readily leached from soils into water bodies and the water table. It can also directly enter water bodies by runoff and through atmospheric deposition. While nitrate occurs naturally in surface waters, elevated concentrations of can damage ecological quality through eutrophication, acidification and direct toxic effects on some species (DEFRA, 2008).

Geograph/Brian Robert Marshall

Timing and precision of fertiliser application minimise the risk of loss of nutrients to water courses. Good practice suggests that applications should be at least 10m from ditches or any surface waters.

Levels are particularly high in lowland areas dominated by arable agriculture. Nitrate loss is encouraged by over application of fertilisers and significant periods of bare soil during winter months (Dampney, 2002).

In areas of mainly pastoral farming and where rainfall is high leading to dilution of nitrate concentrations in soils, concentrations in water bodies tend to be lower. Nitrate concentrations from grassland systems depend upon the intensity of stocking and management, and the use of manures. Too high stocking and autumn application of manures increases nitrate loss (Dampney, 2002).

Nitrates can also enter water bodies through direct or indirect deposition from atmospheric nitrogen. The pollutants that contribute to nitrogen deposition come mainly from nitrous oxides (NO_X) and ammonia (NH_3) emissions. Agricultural sources of nitrous oxides derive from soil management and from management of animal manures.

Despite reduction in emissions, nitrogen deposition from the atmosphere to plant surfaces, the soil and water bodies, remain above the critical load for nitrogen eutrophication for much of the UK (Sutton et al, 2004).

A number of factors, including rainfall, affect the level of nitrogen deposition. Deposition to woodland is greater than to other, shorter vegetation. Although this can make sensitive woodland habitats more vulnerable to deposition, this property can be exploited by using woodland created in the lee of pollution sources, in order to protect water bodies.

Nitrogen losses from woodland are much lower than agricultural land, reflecting both lower or no inputs of nitrogen into woodland systems, and the buffering capacity of, particularly young woodland. While a change of land use to woodland might reduce total nitrogen entering surface water, this is rarely a practical or acceptable option for many farmers since it can result in the loss of significant areas of productive land. However, the use of woodland buffer strips or shelterbelts along watercourse or around water bodies, can also reduce nitrate leaching from adjacent fields.

Phosphates

As with nitrates, phosphates mainly arise from application of inorganic fertilisers and animal manures. About 25 per cent of the phosphates entering rivers are from agricultural sources (Donnison, 2011). The principle pathway for phosphates entering water bodies is through soil erosion and overland flow; phosphates attach to soil particles. Many agricultural soils are enriched with phosphate due to large applications of phosphate fertilisers over many years (Donnison, 2011).

The peak for passage into water bodies is during storm runoff. Some of this will be immediately flushed downstream, but in slow moving rivers it can be deposited with the soil particles and act as a reservoir for phosphate discharge into the water.

Intensively managed grassland can also be a source of dissolved reactive phosphates catchments from the surface applications of manures and accumulation of soil phosphorus.

The main impact and effect of enrichment of freshwater water bodies by phosphorus is eutrophication.

Pesticides

Agriculture and horticulture use over 80 per cent of all pesticides in England and Wales (Environment Agency Wales, 2009). Agricultural pesticides can pose a risk to water bodies through direct contamination as pesticide spray drift, or as a result of pesticide in surface water runoff. Pesticide can also enter water bodies though accidental spillage or inappropriate disposal of pesticide concentrate or spray tank residues. Regulation and guidance on the use, application and disposal of pesticides includes protection of water bodies, nonetheless, pesticides pose some residual risk.

The exact impact of any pesticide depends upon its specific characteristics, climatic conditions, soil type, topography and so on. For instance herbicides tend to have most impact aquatic vegetation, which insecticides are most likely to affect invertebrate species. Agrochemicals that are water soluble and have a high persistence are of greatest risk (Borin et al, 2004).

Geograph/Mike Richardson

Soil sedimentation is a major issue for water quality, damaging aquatic habitats. About 70 per cent of soil sedimentation is estimated to come from agricultural sources.

Soil sedimentation

Sediment has a direct effect on water bodies, through increased turbidity and sediment deposition, while also carrying with it phosphates and pesticides. Because sediment may be carried downstream, and can be differentially deposited by particle size, the exact location and type of impact can be some way from the point of entry into the river. Increased turbidity can affect the gills of some fish, and their ability to feed. Deposition of sediment on gravel beds can affect spawning of fish species and impact on economically important fresh water fisheries.

However the impact of increased sediment levels (beyond that which would naturally occur at certain times) affects the wider ecology of the water body. Increased turbidity and reduced light levels can affect primary production by aquatic plants. The sediment can also increase heat absorption, leading to higher water temperatures affecting the growth of fish such as salmon and trout. Many invertebrates are also adversely affected by sedimentation.

Soil sediment enters water bodies through natural erosion of rivers banks, from surface runoff and through drainage channels. However, around 70 per cent of soil sedimentation of water courses is estimated to come from agricultural sources (DEFRA 2008). Susceptibility to soil erosion is affected by farming system, soil type, local climate, and topography, all of which need to be considered when assessing risk.

Sediment losses are greatest from arable land, with late sown cereal, potatoes and sugar beet particularly vulnerable. Bare soil surfaces exposed to heavy rain leads to formation of rills or runoff along tram lines (Silgram et al, 2010). Areas of compaction and loss of soil organic matter also reduce infiltration and water retention and exacerbate runoff and erosion.

The main problem with grassland is where livestock have direct access to the water's edge and can destabilise banks. Whilst part of the process is natural, trampling and poaching of river banks by cattle can increase the rate of bank erosion. Similarly poaching in gateways, around cattle feeders and water trough or as a result of high stocking rates during wet weather, can all significantly increase the rate of runoff and increased sedimentation. Outdoor housed pigs, where there is a high degree of soil disturbance and poaching, can also lead to erosion.

WTPL/Pete Leeson

Cattle can destablise river banks, increasing the rate of erosion.

Eden Rivers Trust

Targeted tree planting can help mitigate pollution from agriculture, stablise river banks and help improve aquatic habitats. Tree planting on farmland along the River Leith in Cumbria.

Integrating trees in to farming systems

Whilst changing agricultural practices are an important first step in reducing pollution problems, some residual pollution will persist. Targeted tree planting has been identified as one of the ways to mitigate pollution from agriculture and deliver the quality standards of the WFD (Farmer and Nisbet, 2004).

Whilst recognising the role that woodland management, and especially large scale forestry operations, can play in affecting water quality and peak flood flows, the focus here is on measures on farms. The use of trees and woodland integrated into farming systems can help to reduce the risk of harm to water quality, and contribute to mitigation of flood risk, while also helping to support agricultural production.

Previous research, particularly by Forest Research, has looked at the role of trees and woodland in water management (Nisbet et al, 2011). The research identified the need for better guidance to farmers on woodland creation and management for water, and for demonstration sites. This report aims to relate the research to specific measures which farmers might undertake to protect water quality.

Individual farms and water projects will have particular concerns reflecting local circumstances, for instance the predominant farming system, the nature of the pollution source, local weather patterns and so on. The evidence and advice should be tailored to meet these particular needs and practical considerations.

The role of trees and woodland

The role of trees, woodland and other associated habitat in helping to mitigate the impact agricultural practices on water quality is to intercept the pollution pathways and capture pollutants. Pollution pathways can include atmospheric gaseous or particulate transmission (such as ammonia from livestock units or spray drift of pesticide), overland runoff (such as soil erosion and concomitant phosphate loss), or subsurface movement through drainage channels (such as dissolved nitrates).

WTPL/Rory Francis

Native tree shelterbelt

This includes the physical interception of soil particles and, in some circumstances, the absorption by the trees and other vegetation of the pollutants - for instance of plant nutrients. In others, biochemical processes remove or reduce the potency of the pollutant – such as the conversion of ammonia to nitrate or the capture of faecal pathogens within tree belts (Borin et al, 2005, Bongard, 2009).

Where they are present, existing hedgerows and shelter belts may already be helping to reduce impacts on water bodies.

New trees and woodland

There are a number of ways in which trees, shrubs and other vegetation can be incorporated into farming systems to mitigate pollutants and safeguard water resources.

Field margins and riparian buffers

Trees can help reduce soil and water movement by increasing water infiltration rates and slowing the flow of transported sediments. Organic matter added from leaf litter and root debris can also promote soil structure reducing surface water run-off. By trapping pollutants bound to soil particles, trees can help reduce water pollution, acting as nutrient sinks. Phosphates in particular are associated with trapping of sediment, while nitrate removal can occur by plant uptake.

Woodland buffers on mid-slope and down slope field edges, can be effective in increasing water infiltration (Calder, 2008), reducing and slowing runoff and intercepting nutrient and sediment. Studies at Pontbren in mid Wales found that water infiltration increased by 60 times within 5m of tree shelter belts after just 3 years of planting (Bird et al, 2003).

Studies in the USA and New Zealand show that buffers composed of grass, trees and shrubs can be effective at lowering levels of sediments in run-off (Hussein, 2007). While studies from Europe and North America show that phosphate can be removed by tree/grass buffers, a UK study showed that 99 per cent of subsurface nitrate applied to a nearby arable field could be removed by grass/tree buffer and that most of the nitrate was removed in the first 5m (Haycock and Pinay, 1993). Further work in Poland, Italy, Estonia, USA, and Canada has also shown that tree/grass buffers can be effective at reducing nitrate levels in runoff.

The width of the buffer, slope, gradient, amount of vegetation and leaf litter, and soil type will all influence the time taken for water to pass through the buffer. The longer the buffer holds the water, the better it will function. Slopes of more than 7 degrees are not suitable for buffers as water flow is too fast. Planting across the contour or in areas known to be vulnerable to runoff will provide the greatest benefit; knowledge at a farm level will be able to match this ideal to the practical opportunities.

These features can be incorporated into the farm in ways which support other functions, for instance in providing shelter for livestock, pasture or arable crops. Targeted tree planting on arable or pasture can reduce water run-off and the risk of flooding. In addition, shelter belts of trees can have a positive impact on pasture growth by increasing water infiltration. The fencing around new planting can be used to control the movement of livestock, excluding them from river and stream banks and reducing the risk of further damage and erosion.

Riparian and floodplain trees and woodland

The extent of riparian woodland has declined in many areas, but there is a large body of research demonstrating the potential value of such woods as a natural feature of healthy, functioning watercourses. Riparian woodland can aid sediment removal and erosion control, and protect water quality by buffering from pollutants and nutrients.

WTPL/Pete Leeson

Buffer strips of trees and other vegetation can help reduce sedimentation and filter other pollutants.

Evidence shows that riparian and floodplain woodland, in addition to acting as a barrier or intercepting sediment and chemical pollutants, also contributes to protecting river morphology (the shape and form of the river channel) by helping to stabilise river banks.

The dappled shade provided by riparian trees helps to lower water temperatures and can be associated with improved oxygen levels to the benefit of fish and other wildlife. Shade influences growth of aquatic plants, freshwater algae and ground plants, and moderates water temperatures. Current Forestry Commission guidance is that 50 per cent of the stream surface should be open to sunlight with the remainder covered by dappled shade. Planting trees along stream banks could help protect sensitive fish such as salmon and trout from rising temperatures as the climate warms.

Targeted floodplain woodland can be effective at delaying flood flows, potentially reducing downstream flood risk, for example, by allowing time between flood contributions from tributaries to a main river.

Aerial pollution

Planting field margins, where fields are subject to application of manures or fertilisers, allows for capture of ammonia, The woodland edge is especially effective at capturing air borne pollutants, and so a series of small woods or shelterbelts can be more effective than one large wood, due to the increase in edge to area ratio. Small woods and shelterbelts may also fit in better with the farming system.

The scavenging capability of trees planted to capture aerial pollutants depends on species type and the level of canopy closure. Mixed species woodland appears to increase the ability of a tree belt to capture pollutants, while open woodland with young trees promotes through flow of air and also leads to greater scavenging (Prusinkiewicz et al, 1990).

Shelter belts of trees can be an effective way to lower the risk of spray drift, and have been shown to reduce drift by 60-90 per cent (Ucar and Hall, 2001; Lazzaro et al, 2008)

Tree belts also provide shelter for crops or livestock. Shelter has been shown to increase yields of crops, compared to unsheltered crops, through reduction in water loss, particularly in dry years (Donnison, 2011).

Buildings and yards

Farm buildings and yards represent a potential source of both air borne and surface pollution; emissions from livestock units, storage of slurry and manures, potential spillage of fuel and chemicals, and so on.

The design and siting of new woodland needs to reflect the specific risks posed. For instance consideration needs to be given to wind direction when planting a tree belt to intercept ammonia emissions from animal housing. Buffers of trees around livestock housing, or next to slurry and manure storage, can 'scrub' ammonia from the air reducing the amount carried downwind.

Tree belts can also act as buffers against smaller accidental spills from manure or slurry storage areas or runoff from farmyards.

In addition to any benefits to pollutant capture, planting around livestock housing can lower wind speed, reducing the chill factor for livestock, and lowering heating costs to other buildings. The lower wind speed also reduces problems with dust inhalation for livestock and farm staff.

WTPL/Pete Leeson

Open muck heaps can be a major source of water pollution.

Willows are quick to establish and provide a filtering and stablising effect. *iStock/Ulrich Knaupe*

Species choice

Native trees appropriate to the site are preferable to achieve wildlife benefits. If there is semi-natural riparian woodland nearby this might indicate which species are appropriate, but if in doubt advice should be sought.

Alder, which fixes nitrogen in the soil and may enhance nitrate concentrations, should not be planted at a large scale in areas at risk of acidification, or where Phytophthora disease is a risk. Phythophthora alni is a fungal disease that causes dieback of alder species. Special care should be taken not to introduce the fungus to remote riparian sites through planting.

For woodland to act as a nutrient sink, fast growing species such as willow and poplar can be beneficial. They are quick to establish and rapidly provide a filtering and stabilising effect. Willow has multiple benefits because of its dense root structure, and its wildlife value – it harbours a wide variety of insects, which can provide a food source for fish. Planting a wide variety of trees and shrubs will help to achieve varied structure, will benefit a wider range of wildlife, and will prevent heavy losses if one species is hit by disease.

Bank stabilisation requires large root systems, but taller trees can also fall, causing bank erosion. Coppicing (and pollarding) are ways of keeping the height of the tree manageable, while retaining a healthy root system. Trees managed in this way have the potential added benefit of providing a source of wood, for instance for fuel, so long as this can be extracted easily and without damaging the ground.

Light within the tree belt should be adequate to sustain a cover of herbaceous ground flora and marginal vegetation. When choosing species and designing a planting scheme thought needs to be given to how high trees will grow, and how they will be managed in the long term – thinning and coppicing give options to manipulate the amount of shade.

Large woody debris in streams can be of benefit (this includes trees, branches or root plates that have fallen into watercourses), forming a vital component of healthy functioning watercourses. Woody debris helps to vary the flow and shape of the channel, creating physical habitat for many species of plants, invertebrates and fish. It can improve the resilience of river ecosystems to the impacts of climate change.

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Farming in Salisbury.

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