GWCT BRIEFING

Management of clay soils to reduce impacts on water – the evidence base from Allerton Project research

BACKGROUND

Agricultural land use can have negative impacts on stream and river water quality because of runoff and loss of soil and nutrients from fields to watercourses. Evidence from the 1,000ha Eye Brook headwater suggests that 300 – 1,000 tonnes of soil enter watercourses from land each year. Much of the phosphorus in water is associated with this soil as phosphorus is bound tightly to soil particles. In a small catchment at the Allerton Project's farm at Loddington, 95% of the annual phosphorus load in the stream was estimated to be from agricultural land (Jarvie *et al.*, 2010), whereas at the scale of the 3,000ha Water Friendly Farming project headwaters (Stoate, 2023) and the Welland river basin as a whole (Rothwell *et al.*, 2021), the proportion from agricultural land is around 40%.

Reducing the loss of soil, phosphorus and other nutrients from land that is used for food production can be difficult as fine particles associated with clay soils are held in suspension over long distances in runoff, and runoff rates can be high on steep undulating slopes, especially in the upper reaches of river basins. However, Allerton Project research suggests that there are steps that can be taken to reduce runoff and impacts on water quality. The same management practices on agricultural land also help to address the increasing public concern about flood risk by reducing the flow of water from farmland to watercourses and sedimentation of drainage channels.

REDUCED CULTIVATIONS

Reducing cultivation intensity by adopting shallow non-inversion tillage or direct drilling approaches to crop establishment can reduce soil and nutrient loss to water. One experiment at Loddington recorded 0.8mg of phosphorus per litre of runoff from ploughed plots, compared to 0.1mg per litre from reduced tillage plots for example (Cooper, 2006). Laboratory experiments using soil from the plots suggested that this was largely due to the development of fungal hyphae in undisturbed soil (Allton, 2007). Another experiment recorded reductions in soil loss to water of 34-62% in reduced tillage plots compared to plough (Deasy *et al.*, 2008). Crop yields can be lower than those associated with ploughing, especially in the early years of transition, but this is offset to varying degrees, depending on soil type and growing conditions, by reduced cultivation costs.

MINIMISING COMPACTION

Water infiltration rates vary considerably and, in some fields in the Eye Brook catchment, have been found to be an average of forty times higher in relatively well-structured parts of the field than in compacted areas of the same field. In addition, tramlines are a major pathway for runoff and soil and nutrient loss to water and the use of low ground pressure tyres can help to reduce runoff rates (Silgram *et al.*, 2015).

Low disturbance subsoiler.

Where compaction occurs in direct drilled fields, the use of a low disturbance subsoiler can be an effective option, without the negative impacts on soil structure and biology associated with ploughing. In our experiment at Loddington, subsoiling was comparable to ploughing at reducing impacts of compaction on yields, and was marginally more cost effective (Bussell *et al.*, 2021). In direct drilled systems, subsoiling therefore provides a means of reducing negative effects of compaction on crop performance and water quality while maintaining other the aspects of soil biology and function associated with direct drilling.

INCREASING SOIL ORGANIC MATTER

Evidence from arable fields around Loddington suggests that where soils are not compacted, soil organic matter has a significantly positive effect on water infiltration rates, helping to reduce surface runoff and soil and nutrient loss to water, and potentially reducing flood risk downstream (Stoate, 2023). A number of management practices can contribute to an increase in soil organic matter, at least close to the soil surface. These include direct drilling, application of manure or digestate, cover crops, and grass leys within the arable rotation.

COVER CROPS

Cover crops are known to reduce surface runoff and take up nutrients which might otherwise be lost to water. Allerton Project research suggests that they can also help to reduce blackgrass populations in the cover crop themselves, and in the following spring crop (Crotty & Stoate, 2019; Lee *et al.*, 2017). There is some evidence that species such as oats and Phacelia help to make phosphorus that is bound to soils more readily available to crops by increasing phosphatase enzyme activity, but this is not conclusive (Reynolds *et al.*, 2017). Benefits of cover crops are only realised if establishment is good which can be difficult to achieve on clay soils and following late harvested crops. Cover crops also need to be destroyed early to ensure an adequate seedbed for the spring crop. Although they help to reduce soil and nutrient loss to water, cover crops have proved to be marginal, at best, from an economic perspective.

GRASS BUFFER STRIPS

Grass buffer strips adjoining water courses are widely adopted as a means of increasing surface roughness, reducing runoff and increasing sediment deposition in the field margin, but these can be breached where the gradient is high and the topography concentrates flow. Evidence from Loddington also suggests that water infiltration rates in buffer strips are often no higher than in adjacent arable land, possibly because of compaction associated with vehicles. However, earthworm numbers can be at least 2.5 times higher in grass margins than in the adjacent field (Jones, 2014), increasing channels for subsurface flow, and plant species in seed mixtures can be selected for their deep-rooting to further increase infiltration rates.

Grass buffer strip.

BEETLE BANKS

Low banks sown with coarse grasses across sloping fields can help to reduce runoff. Sediment can accumulate upslope of banks so that runoff subsequently over-tops them, but average water infiltration rates within a beetle bank have been found to be six times higher than on adjacent arable land.

DEEP ROOTING GRASS LEYS

Grass leys within arable rotations reduce the frequency of cultivation, increasing soil stability, structure, organic matter and biological activity and can consequently reduce soil and nutrient loss to water. Including deep-rooting agricultural grass cultivars in seed mixtures potentially increases water infiltration rates. In a recent experiment, one Festulolium cultivar was associated with an average infiltration rate that was nearly four times that of a standard ryegrass and clover ley mixture (Stoate *et al.*, 2021). However, shallow compaction associated with late autumn grazing by sheep, and intensive harvesting of silage, reduced the rooting capacity of grasses and the potential for improving infiltration rates. The results suggest that benefits associated with deep rooting grasses are dependent on relatively low intensity grazing or harvesting and avoidance of compaction.

SEDIMENT TRAPS

Sediment traps that are designed to capture sediment before it enters watercourses provide a clear visual and easily costed measure to address diffuse pollution. However, the evidence from the Allerton Project is that they are ineffective on clay soils where fine particulate matter is held in suspension for long periods and the retention time of sediment traps is too low to capture this fine suspended sediment. A three-year study of three sediment trap designs at Loddington revealed very minimal accumulation of sediment or nutrients, although the same designs were more effective on silt and sand soils elsewhere (Ockenden *et al.*, 2014).

Deep-rooting grasses.

SUMMARY

Reducing loss of soil and nutrients from productive land is challenging where there are clay soils and undulating topography. End of pipe approaches such as sediment traps have limited potential. However, if carefully managed, there are several measures that can be adopted at the field edge and within the productive area to maintain food production while also reducing negative impacts on water quality and aquatic ecology, and potentially reducing flood risk.

Well structured soil from a long-term direct drilled field at Loddington.

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