Natural England Commissioned Report NECR100

Managing soil biota to deliver ecosystem services

Annex D – Case study four: Arable cropping

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Arable cropping: Heavy (clay) soils and some fen peat

- No till includes non-inversion tillage.
- Overwintered stubbles.

No sign tells us to "beware snakes" as we drive up to the farm, but the message from farmers who have visited A's zero till system is that the worms are big as snakes. The arable rotation isn't very different from that of neighbours with 1st and 2nd wheats, oilseed rape and some spring-sown crops - spring beans/oats. But the difference is clearly seen. The farms around have brown soil on show, on A's land there is stubble, straw mulch and growing crops, but no soil to be seen. The crops are drilled through a mulch of residues on the soil surface. Now, in spring, when you stop to look you can see that the lob worms have been sweeping the ground and making piles of straw over their near vertical burrows. A uses the trowel he has in the cab and proudly shows off the crumbly topsoil (4-5 inches deep) around the monster worm hole.

Changing the soil has led to other changes above ground. Lapwing nests continue to increase; brown hares lurk on every side. The increased worm count has brought in birds and the birds that eat the birds that eat the worms. It's due to the whole system with better overwinter cover/ shelter too. "When the rest of the parish turns brown anything that can fly/walk comes here". Through the winter there are flocks of starlings making home in the stubbles, and woodcock and snipe. Mice numbers are up. "We've seen more bumble bees in spring, we wonder if they are using mice nests to overwinter? **The increase in soil activity is driving the whole system**".

The lob worm – *Lumbricus terrestris* – is Britain's largest earthworm and can be up to 35 cm long when moving. They live in deep vertical burrows (part of the anecic functional group) and emerge at night to feed on decaying organic matter. They can anchor themselves by broadening their tail to grip the sides of the burrow and create distinct middens where mineral soil, shredded organic materials and surface casts are mixed together close to the burrow opening. More information on British Earthworms can be obtained from the Natural History Museum, **www.nhm.ac.uk**.

Cover provided by crop residues, along with weed seeds and waste grain for food, and less disturbance from field operations favours graminivorous species. The structural diversity of the crop residues and stubbles also provide insects, including carabid beetles and spiders, with a protective environment and hence support insectivorous species of birds and small mammals. Morris *et al.* 2010.

Ten years ago it was very different. The land had been ploughed for over 100 years – with increasing intensity over time and each year the plough brought up the grey layer of last year's undecomposed residues. "**We'd lost soil structure and so we used lots of fuel to beat the land into submission** - we needed 700 hp to drill in spring. Then I remembered that my grandfather had worked the land with one horse. It made me stop short to think about what we were doing – it wasn't working that well, we had to be able to do it better". There were also problems with wind erosion – "the fine dust we were making through tillage was creating dense clouds – so that on one occasion a policeman asked us to stop as we were endangering the traffic". Some of the land was in a pilot catchment sensitive farming area so A attended talks and started to talk to the advisors – phosphorus in fine sediments was blowing into water courses. "**It just seemed sensible to keep your own soil on your own farm**".

A had tried min till approaches; he feels that, on his land, cultivator drills give no real advantage over ploughing – perhaps even less –any cultivations were breaking the dormancy of weed seeds and there were more problems with weeds. A was aware of the 1970s work on direct drilling supported by Gramoxone herbicides; but the availability of herbicides to control blackgrass and the easy availability of glyphosate as a herbicide meant that that zero till approaches were worth a second look. A read and read; the work of Edward Faulkner (Ploughman's Folly, 1943) gave him lots of ideas then after lots of thinking a local agronomist challenged him – " Plough or don't touch it – there is no half way". Before committing to the system, A went across to France to look at systems that had been in place for years – "It was important to see it for real; just fascinating".

Tillage is the manipulation, usually mechanical, of soil properties to modify soil conditions usually for seedbed preparation and/or weed control. Where a soil has a strong and resilient structure little energy is needed to create a seedbed. Soils under agricultural management are most often distinguished by the lower OM levels and weaker structure of their well mixed surface horizons from adjacent soils in semi-natural systems. Soil structural formation and stabilisation depends on a range of physical processes (for example, wet-dry and freeze-thaw cycles) but also on a range of biological processes, which require regular OM inputs to drive them. Decomposition of OM produces a range of polysaccharide and glycoprotein gums which stabilise microaggregates which are then bound together in the faecal pellets of soil macrofauna or enmeshed by fungal hyphae and/or plant roots. Soil organisms (mites, insects, earthworms) move soil particles and microaggregates about to create and re-organise soil pore space – they are considered ecosystem engineers.

Reduced tillage systems for the cultivation of cereal and oilseeds use a sequence (often in a single pass) of tine and disc implements. These lift and shatter the soil removing any shallow compaction (tines) and cut and mix any crop residue of soil clods (discs) to give a fine tilth. Cultivator drills are now common which combine these tillage steps with press wheels and a drill, so that the field moves from residue and stubble to sown tilth in a single pass. In contrast, no-till drills combine a thin disc and carefully aligned drill so that soil disturbance is minimal and a permanent or semi-permanent soil cover is maintained.

In France, A had visited a distraught young farmer whose father-in-law had looked after the farm while he was on holiday (which had been zero till for > 10 years). He thought it looked untidy, found an old plough in the nettles – and ... ! A smiles: “We had a machinery sale so we couldn’t get confused! Everyone on the farm had to be on board”.

From this farmer’s perspective, it is key to have good tools to control weeds (herbicides) and appropriate machines to drill through residues. A is excited about a new drill; it matters that he can adapt it to his needs: “**The drill is the most important piece of kit to get the system to work** – they aren’t a low cost investment and they must be right for my soil and system”. No-till disc-based drills are available but have been largely developed for drier climates, hence they are not always fit for purpose in UK and parts/servicing can be difficult. No till advice from elsewhere (US, Western Australia, South America) is often focussed on moisture conservation and so needs thinking through carefully for the UK.

A is still reading, thinking, looking, keeping records of to monitor his system and getting involved in research projects – he’s been able to provide case study sites to a number of research projects. He is proud that his heavy soils (30-35% clay) have more soil organic carbon (4.59%) than the optimum range predicted by the Keysoil project – the same was seen for all no till systems included. Beetle monitoring with pitfall traps compared the no-till with neighbouring ‘classically cultivated’ land – “They had 4000 individual beetles, I was really disappointed that we had only 1000 individuals – but they only had 2 species and we had an amazing 23 species – we think that might explain why slug problems seem to be getting less damaging with time – perhaps the range of beetle species provide constant predation on slug eggs”.

The adoption of no till or conservation tillage approaches is qualitatively different than the adoption of a new variety or crop protection product, which would require only minor adaptations of the existing cropping and tillage systems at farm scale. The “conversion” to no-till is widely recognised to be complex and lack standard procedure; this requires more of the operator in terms of management skill, experimentation to achieve effective local adaptation.

Clay contents and precipitation were determined to be the most important factors in predicting soil OM contents (Verheijen *et al*. 2005). Within the physiotopes defined by clay content and total annual rainfall, management practice within arable systems had a important effect as it determined both the amount of OM inputs in crop resides etc and the rates of turnover and stabilisation of any OM inputs within the soil. No till systems are likely to have both increased OM inputs and increased OM stabilisation. Soils under permanent grassland have even higher soil OM contents on average.

The costs of cultivations are now much lower – "The average cost of all arable operations when we were conventionally cultivating was £96 / ha in diesel alone". The farm has now replaced 3 or 4 cultivation steps (subsoil, plough, disc, spring tine, row harrow, drill or roll) with a single drill step –reducing total diesel costs to £42 /ha and there is much less machinery in the shed to depreciate. "We have a sprayer, spreader, drill, combine – that's all! When I go to the machinery dealers they now groan: 'Proper farmers sell me a little one and buy a bigger one – you sell big and buy smaller'".

Timing is critical on these heavy soils – there has been no extension of the drilling window – "we must get in before it starts getting wet". Varieties are selected for early drilling and behind the stripper header combine, oilseed rape is autocast into the standing straw, with good success, even germination and good yields. A's video footage of wheat drilling shows no evidence of soil disturbance at surface at all (except by the markers) and I can hear A's intake of breath: "**You find yourself feeling guilty if you see even the smallest amount of soil moving**; we have become jealous of it". Out in the field we have to go down on hands and knees to see the disc slot amongst the straw mulch – and it's only really found because the green tips of the oats have started to emerge. Over lunch Mrs A comments without prompting that the spring crops drilled the same day as the neighbour are through faster, she links it to the better moisture retention in the no till system in this dry spring.

The benefits aren't all instant; "**It takes soil a little while to get the hang of the job** – on our heavy soil, year 3 is the most difficult then benefits begin to be seen. For us, by year 6 we are out-yielding our classic cultivation approaches. The dip isn't seen in all soils; lighter soils seem to settle in quicker".

In the US, fuel costs are a key reason for adoption of no till systems. So for example – the University of Tennessee estimates that fuel costs for corn planted following ploughing, discing, and cultivating is estimated at $14.17/acre, while fuel cost for no-till corn is estimated at only $9.14. They also highlight the advantages that accrue if smaller tractors are needed. Fuel cost for a 70-Hp tractor is estimated at $6.13 per hour, while fuel for a 100-Hp tractor costs $8.76 and for a 150-Hp tractor costs $13.14 per hour – see **http://agriculture.tennessee.edu/**

Increases in the proportion of rainfall infiltration versus run-off and improved moisture retention are common observations in comparative studies of no till and conventional tillage systems – these changes result from both changes in soil OM contents and soil pore size distribution and its stability.

Although the need for conversion periods for soils under no-till is a frequent farmer anecdote, Simmons and Coleman (2008) showed no clear chronosequence in the development of soil microbial communities with increased biomass and diversity following cessation of tillage; they hypothesised that any apparent "conversion period" for soils in conservation tillage (no till) system occur only where soils had previously received very low inputs during conventional cultivation.

The same principles of minimum disturbance are used on the fen land – "It's funny stuff. Using it, it burns up, dries out and if you move it blows away fast". A is now trying to keep his land still and catch any that his neighbours are letting go. Monitoring is in place as the fields are on the edge of an SSSI and the soil seems to be staying put due to zero-till approaches, even under arable crops.

Dry and bare sandy soils with weak soil structure and cultivated peaty soils are at highest risk of wind erosion. In the UK, areas at highest risk are East Anglia, East Midlands and the Vale of York. Consequently no till systems reduce wind erosion risks significantly due to the presence of a soil cover and very limited soil disturbance.

A's kitchen sees a large number of visitors and he gets a lot of invitations to share what he's up to – "People are looking at their machines and getting worried about diesel prices". He smiles and tells me about waiting for a big tracked tractor with a huge plough to cross the road, he expected to hear a 'wow' from his grandson – but instead he heard "What old fashioned farmers!" A's isn't interested in telling people what they should do – "**every soil is different and you need to know then and how they will respond** – it's not always easy to predict – so I just show people what I've been doing and let them think it through for their systems".

As with all tillage systems, impacts and effectiveness of tillage systems depend on multiple interactions between soil type and weather patterns. "It is difficult to visualise, let alone predict, the soil conditions resulting from any given operation" (Unger and Cassel, 1991).

A's joy in the whole farming system and its interconnections was palpable as we drove round. I asked if he'd always felt this way. "I've always loved farming. But ten years ago I was focussed on getting a bigger tractor, increasing yields. **Intensification of farming systems has let us get away with poor soil management but look at the trends – lower trace element concentrations in food, bigger kit needed, costly inputs substituting for good management**. Now I'm excited about the processes of farming with / alongside nature. It's a joy to see it all. I'm discovering something different all the time. Zero-till means I've begun to view the job differently, look in different ways. **The main asset on the farm is soil – better soil activity enhances your asset, why wouldn't you want to look after it**."

Intensification of agricultural production is commonly associated with increased use of mechanical and manufactured inputs; Giller *et al.* (1997) found that during intensification regulation of the agro-ecosystem through biological processes has tended to be replaced by regulation through inputs. No–till / conservation agriculture systems seek to link increased OM inputs and reduced tillage intensity to optimise biological functioning without a reduction in intensity of production in combinable cropping systems.