Natural England Commissioned Report NECR100

Managing soil biota to deliver ecosystem services

Annex A – Case study one: Mixed farm range of livestock enterprises and arable cropping

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Mixed farm range of livestock enterprises and arable cropping: Medium loamy soils with flints over chalk

- Use of green waste compost, mushroom compost, paper waste, coffee grounds ie application of (local) waste organic matter.
- On farm composting using a range of advanced techniques to develop site specific composts.
- Use of compost teas as soil treatments.
- Integration of green manures into crop rotations.
- Introduction of diverse seed mixes, for example, deep rooting species and herbs.

"**I'm not prepared to feed just any compost to my worms; it needs to be active and alive to support plant growth and soil life**."
Compost was the first thing K wanted to talk about when soil life was mentioned. The estate was regularly bringing in green waste from the local authority in large volumes mixing in farm waste – largely strawy cattle manure (FYM) - and making compost to PAS100 standards. In the past this had been applied to land regularly - for example, to the leys twice a year at the start of growth and after first cut of silage at about 13 tonnes per hectare. But K had observed that the first compost application had led to a yellowing of the grass and the second to even more nitrogen lock-up – "the whole of the soil life was focussed on breaking the compost down, depleting soil quality and setting back grass growth by up to a month – a month I just couldn't afford to lose". Clover wasn't nodulating and fixing nitrogen, the topsoil had an accumulation of undecomposed lumps of compost.

All in all it was potentially disastrous. It was time to look again at the composting processes and to refine the process turning the crude material produced by the current system into real fuel for soil and plant health.

Nitrogen lock up is associated with the incorporation of organic materials with high C:N ratios. To break the materials down effectively soil biota scavenge nitrogen from the pools of available N in the soil outcompeting plant roots and cause N deficiency symptoms = plant yellowing. Organic inputs applied during periods of active plant growth should ideally have a C:N ratio of less than 20.

Different legumes secrete different types of signals (usually phenolics) and rhizobia have different NodD proteins (frequently more than one) which recognise these root- exudate signals. In many legumes such as peas, clovers, vetch, alfalfa and beans, infection is then usually initiated by bacteria, which have become attached to the root near the tips of root hairs. They produce Nod factors, which cause the deformation of the root hair which bends back on itself, entrapping bacteria in a so-called 'shepherds crook' structure- (Downie 2010 summarise many of the mechanisms involved).
As well as plant signalling via exudates, a range of external factors including nutrient availability, pH etc can affect nodulation and the effectiveness of subsequent N fixation. However, the factors affecting nodulation under field conditions are not well understood.

K noticed the impact of the seasons on the input materials and hence the final compost: "The best compost comes from the finer materials when everyone is cutting their grass and clipping hedges; autumn isn't too bad with fallen leaves making up a large part of the substrate but winter composts are dominated by tree prunings and old wood". **Understanding inputs is key to controlling outputs in composting**.

K also felt that the heat generated during composting was sterilising – good for the composting bacteria and to reduce weed burdens but not great for the ordinary soil bacteria and fungi. The compost wasn't right or fit for use, it needed to be played with – and allowed to grow on after the process. So K introduced his own on-farm maturing process to the end of the PAS100 composting. The compost was stacked in field windrows and fresh strawy FYM mixed in (1 load to 2 loads of compost) to feed the organisms and allow them to re-invade the compost from the FYM. After 3-6 months K feels that he has the biological activation he needs: "T**he matured compost is not a foreign body, the soil life recognises it and is able to use it straight away**". The matured compost is applied in the same way but has very different results, it immediately makes grass greener. The topsoil has become darker over time but there are no clear lumps of compost remaining.

Danon *et al*. (2008) monitored the succession in the microbial communities responsible for the composting process using molecular methods. They highlighted that successful application of compost is considerably dependent on the selection of an appropriate curing period. Significant changes in the compost microbial community took place after the point when a commercial composter considered the compost appropriately mature for field application. During the additional maturation period, the microbial community became increasingly unlike the expected typical compost bacterial community and became increasing adapted to the use of slowly decomposable substrates.

Jenkinson (1966) defined priming effects as changes in the mineralisation rate of OM as a response to some addition of fresh OM inputs. Addition of low C:N materials causes a smaller additional decomposition of existing OM than high C:N inputs. In this case mixing of materials with different C:N ratios and different microbial communities would lead to complex interactions including cometabolism, competition or mutualism between the microbial communities (Guenet *et al*. 2010) with resulting changes in decomposition and N dynamics during the 3 month maturation phase. The outcomes seen in the field here suggests that the mature material has a lower C:N ratio making it more decomposable in soil and perhaps more immediately available N.

K is not convinced that he has yet got the composts right. His aim is to use inputs of composts to support the fungal activity in the soils – the system of cultivation in place favours bacteria anyway. The farm has the capacity to brew its own compost tea; in the future, compost tea brewed from the best quality composts might be used as a starter to the maturation process rather than all that FYM. K feels that compost tea would also be an excellent soil amendment after subsoiling or aerating taking active soil organisms into the heart of the soil/root system.

Driving around the farm, K points out soil problems from the cab. “I do like digging” he hastens to reassure me, “**but I can also look at the soil through the crops**”. He shows me how compaction around the field gate (quite a long way into field), around a winter feeder and along a track way in grassland is highlighted by the change in above ground species. “Where there is plant-constraining compaction, dandelions and meadow grasses outcompete the Italian ryegrass in the mixture, so I know it needs breaking”. K talks of the need to combine physical (tillage) and plant mediated approaches to managing and remediating soil structural problems: “**Through our cultivations we seek to help structure formation and ensure we support the biological processes which stabilise and strengthen the pores for the whole rotation, not just this crop**”. Chicory is included in long term grazing leys: “It has stock health benefits but it’s also able to root through compacted layers in subsoil.” In the long term leys, the ground is largely untouched so the soil biology gets to do its own work without interference, K therefore focuses his management as he establishes his leys on “**making the best possible conditions for the soil organisms** as they go in to the ley so they can work hard for me”.

Studies of the use of compost tea as a soil amendment under field conditions have found little effect on soil biota other than might be predicted from evaluation of the nutrient content. Studies of composts have shown excellent biocontrol properties in greenhouse cultivation of tomato; however, Ntougias *et al*. (2008) found that there was no common critical biotic or abiotic variable that determined the suppressive effects of composts on soil-borne diseases; they highlighted the need for individual evaluation of compost products for specific uses and the development of standardised compost production and storage routines. This will also be true for the selection of composts for the extraction of compost teas.

The restoration of the physical structure of soil by plant roots depends on the ability of roots to penetrate strong soil. Lofkvist *et al*. (2005) compared the effectiveness of a number of plant species in rooting through a hard layer at 5 cm depth and found a clear difference between species: barley < chicory = lupin = red clover < lucerne

In this farming system it is the pigs that make the soil most unhappy – especially when any green cover is lost over winter. The driver for the numbers of pigs is continuity of supply for the market so stocking density is difficult to match to changes in carrying capacity by season. Following pigs K has found that the soil is dense and hard with no air – but there is plenty of N; “I need to give the soil time to pause and rebalance – often I’ll drill stubble turnips chosen as the seed is cheap and they give rapid ground cover, though the yield is often poor. The roots then begin to form structure from the compacted mess the pigs have left. “It makes it harder for the ploughman because of the modern kit and it’s not as tidy as he’d like, but we never plough more than 6 inches deep – the shallowest the kit and the tyres will let us get away with”.

In outdoor pig systems, rooting and trampling during the stocking period typically leaves the soil surface compacted and without vegetative cover. It is especially difficult to maintain grass cover during autumn and winter. If vegetative cover can be maintained soil structure is protected and nutrient loss risks are reduced (Eriksen *et al*. 2006). However, the options of ringing sows, and reducing stocking density are not often compatible with the commercial requirements of such systems If seasonal stocking can be practiced then pig rooting can be used as an effective precursor to cultivation of winter wheat (Andersen *et al*. 2001).

In the second half of the twentieth century ploughing depths have generally increased in cropping systems across Europe, for example Van Meirvenne *et al.* (1996) showed an increase in tillage depth from 22 cm to 32 cm. The plough depth used here is therefore relatively shallow.

As K got interested in soil management, he heard a series of talks about soil, soil life and composting. But what he heard and what he saw on the ground didn’t quite join up. There was a gap between science and practice. So K checked up for himself, read a lot and began to adapt the general principles to his particular soils and farming system, now he thinks through any advice in light of his own local experience: “**Knowing the land, having a feeling for the soil means you can test and tailor any advice you are given**. It’s also useful to run things round with others, before you identify what you believe to be the answer. Then watch, monitor and compare any changed practices. Just like with the compost I’ve played with what I’ve heard and **adapted the best practice principles for soil life to fit my farm**”.

Sherwood and Uphoff (2000) see the challenge for improving soil management as one of engaging farmers rather than changing them. They recommend that farmers should be directly involved in processes of identifying and prioritizing problems and opportunities, testing and evaluating innovations and being partners in sharing the information gained. Garforth *et al* (2003) consider that facilitation to provide assistance or support in using the information is important as simply making information available.