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Managing soil biota to deliver ecosystem services

Annex B – Case study two: Stockless horticultural cropping

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Stockless horticultural cropping: Sandy clay loam soils with up to 40% stone

- Use of green waste compost, mushroom compost, paper waste, coffee grounds ie application of (local) waste organic matter.
- Integration of green manures into crop rotations.
- Green manure crops incorporated to provide soil fumigation effects – for example, mustard.

"Look at that", T pointed with pride at a series of dark brown piles gently steaming when stirred, piles that at one end were still recognisable as the Leylandii cuttings and other hedge trimmings from a local gardening contractor all collected with 2-3 miles of the field in which we stood. At the far end, where the cuttings had reached 18 months after they had arrived, I was given a handful to smell and the sweet smell of loamy rich soil was almost overpowering. "It's something I'd always wanted to do, to close the circle a bit for the nutrients leaving in vegetables. I stumbled on to it almost by accident talking to friends; it's important that I can trust where it's from, no weed seed contamination and we compost our own wastes with this too now without stimulating the vermin like we used to".
T described how the process was facilitated by the small digger enabling the piles to be turned 4-5 times a year and then wetted down as needed as the piles seemed to always be thirsty. "Once the worms start to move in, it's good enough to go" T declared indicating with a sweep of his arm the strips of green running across the field "It goes on to the green manures and helps to balance out the system for phosphorus and potassium".

The rich sweet smell of soil is a result of the presence of Actinomycetes, a type of filamentous bacteria that grow in soil or compost when conditions are damp and warm. It is the spores that have a distinctive, earthy smell we often associate with rainfall. High population densities of cellulolytic and oligotrophic actinomycetes have been found in mature compost and they may be linked to suppression of soilborne disease (Tuitert *et al.* 1998).

Compost contains essential major crop nutrients and trace elements. The nutrient content of compost varies somewhat, depending on the feedstock and the actual nutrient levels can be obtained from the compost producer. Typically 1 tonne of compost (fresh weight) contains 1 kg P and 4 kg of K. Around 50% of the P and 80% of the K is available to the first crop.

Green manures are at the heart of the rotation. I joke that T seems more focussed on his green manures than the vegetables. He reminds me that the vegetable crops occupy the ground for a short period of time - often only 12 weeks of the year. Hence the green manures are there longer and are chosen to conserve and hopefully enhance fertility. At the field scale, there is a 7 year rotation with 5 cash crops but the soil is rarely uncovered for more than a week at a time. The rotation is planned to use fertility carefully - different root systems, different control methods – as there are no animal manures brought in and no other fertility inputs. It's a relay of green manures and the crops are often undersown. There are differences in soil structure following different green manures, as a result of different rooting patterns and amounts of residue returns. There can be compaction damage in the wheelings – so sowing green manures between the vegetable beds helps to protect the soil structure during the growing season. "If there is a problem getting a green manure in, then the high weed seedbank of chickweed on the site comes into its own!"

The system has been in place for over 20 years but it is constantly evolving. In the beginning T used a mix of grazing rye and mustard as the main green manure. The site had been an intensively cut hay meadow previously; there was a big wireworm problem. Now mixtures are getting more diverse. The first step was to introduce clovers and other N fixers including vetch. "Having more than one species there at once means there is always something there, if one thing doesn't come through then something will." T confides that he is still wary of including grasses "but I have a few grass species in a trial mix – so we'll see what happens with wireworm – the potatoes that follow will tell me". The only problem with green manures comes in a dry spring; the ground can be quite dry after a green manure for the following vegetable crop– but T has a borehole and can use irrigation so this indirect competition for water between crops and green manures isn't an issue.

Each plant species (and often crop variety) contributes a unique root structure, amount and composition of root exudates and residues to the soil. These inputs of C drive the soil food web. An increase in plant diversity, whether in space or time, is likely to lead to an increase in the species richness of soil biota. However, to date, increasing species richness in the soil biota (or a component of it) has not been strongly linked to improvements in soil function.

Wireworm are the larvae of the click beetle. High wireworm populations are usually associated with fields in long-term grassland as this undisturbed habitat is generally favourable for wireworm survival, and therefore crops grown in the first few years after ploughing out grass are most at risk of wireworm attack. Glucosinolate containing plant tissue (for example, mustard) has the potential to reduce feeding activity and reproduction of wireworms (Williams *et al*. 1993). Allelopathic potential against weeds has also been shown by cereal rye when used as a cover crop.

T would love to be able to not use the plough and still keep the diversity of green manures. At the moment the ground is ploughed to 6 inches especially for potatoes; at some points in the rotation the green manures are incorporated after flail mowing and several passes with the power harrow – “But I’m not sure it saves any diesel or disturbs the soil any less. **Cultivations and green manures together are my strategy for looking after soil structure**.” Cultivations are an important step to make the seed beds but for those seedbeds to be resilient and for the roots to be able to explore the soil to depth, then T considers that green manures are an essential accompaniment. “I use cultivation to make it, and green manures to hold it”.

The rotation isn’t perfectly kind to the soil. T talks about the signs of damage to the soil structure that can occur during the rotation – “**but the key is knowing ways for working with your soil to help repair the damage** – I’m lucky my soil can be very forgiving”. The facts and figures about the soil are in T’s mental filing system and instantly available; the particle size distribution in the 8 inches of topsoil is 16-18% clay with the rest fairly evenly split between sand and silt. If it weren’t for the stones (up to 40% of topsoil volume). it would be a good bit of soil. “You wouldn’t think the change from 16 to 18% clay could make a difference but it really is noticeably different to cultivate from bottom to top of the field.”

Soil analysis is used to keep an eye on the sustainability of the nutrient budget. “At the moment I use the above ground to tell me if the below ground is happy. I would love to measure soil biology- but there is no reliable test. I’d like to see how soil life responds to the cycle of my rotation and how my system compares in terms of soil life with one that uses imports of animal muck.”

In intensive vegetable cropping, Overstreet *et al*. (2010) showed that where OM inputs were combined with reduced tillage the combination compounded the effects of the treatments individually in increasing nematode populations (compared with intensive tillage and solely mineral fertilisers); in contrast earthworm numbers responded most to tillage reduction and showed little interaction with OM inputs.

Hence reduced numbers of tillage operations and/or increased duration of no-tillage periods within a rotation are likely to lead to increased biomass of both soil macro- and mesofauna (Van Eeekeren *et al.* 2008). Earthworm numbers are further enhanced where additional food resources are available. However, where intensive tillage is needed, for example, for potatoes regular OM inputs can help offset the negative impacts of tillage.

T also considers that he is also building the soil – “The soil is naturally about 4.5 % organic matter – but I’ve measured only a small increase +0.5% over the 20 years of cropping. It’s hard to get a representative sample and be sure you are really comparing like with like because of the spatial variability and the complex rotation”.

T seems to be focussed on the above ground management, but awareness of the soil underpins all he does. The systems he has in place are all designed to keep the soil in good heart. “Managing the system is not just about managing the crops, it’s about looking after the whole ecosystem – in the past I would have tidied away these stems and residues of the brassicas – but overwinter they provide just the place for predators to hide out. Spatial management matters – where things are, the direction you mow. I’ve planted hedges and rejuvenated others – it is important. It’s the same with soil. **Other folk have focussed on just the chemistry (nutrient management) or just the structure (the right machinery) - but if you look from the point of view of the soil biology you have to think about the whole – as a place to live, eat** …”

Peering down and parting the green manure plants, T exclaims with joy; there is a huge density of earthworm casts. “The worms were late this year” he comments – they were held back by the cold in early spring However, worms aren’t always T’s favourite soil animal, “onion transplants are too expensive to be worm toys” he comments. Onions are transplanted through holes in a black plastic mulch cover – “coming back the next day you find that the worms have been out and turned them all, grasping the green shoot, drawing it towards the burrow and consequently uprooting them. I thought putting chopped straw out might help, but it only seem to make them worse.”

Between 1978 and 2003 agricultural land in the UK generally showed declines in OM content (Bellamy *et al.* 2005); horticulture and intensive cropping systems are generally associated with the lowest soil OM levels (for example, Cotching and Kidd, 2010). The small increase indicated here means that approximately 160 kg of C per hectare is added to the soil OM each year over the 20 year period.

Soil monitoring at a farm scale requires careful attention to variation in space and time; ideally soils should be sampled at the same point in the rotation and in the same spatial pattern each time.

Anecic earthworms, such as the lob worm (*Lumbricus terrestris*) are considered to consume low-quality (high C:N) food materials, mainly litter and other dead OM from the soil surface. However recent studies have shown that they selectively feed on seeds (as well as burying and dispersing them). Eisenhauer *et al*. (2010) have also shown for the first time that these earthworms also act as seedling herbivores; in their experiments the earthworms selected legume seedlings in preference to grass. However, there is no literature on the turning of onion transplants by earthworms.