Questions answered during the Soil Carbon Science webinar, 7 July 2021

Soil carbon storage and measurement

Q: Can we put some figures (%) on soil saturation in different soil types (typical of UK)? Carbon or organic matter might be more relatable.

- Pete Smith: Saturation depends on soil type and climate. For a sandy soil saturation might be around 2% organic carbon - for a clayey soil in a wet area it might be closer to 5% organic carbon.
- Jonathan Scurlock: But note that total organic carbon per hectare is a better measure than % content, since soil structure and depth can also vary and %SOC tends to decrease markedly with depth.
- Liz Stockdale: the AHDB-BBRO Soil Biology and Soil Health Partnership Soil Health Scorecard (finalising now) will include traffic light by texture and climate to give farmers this benchmarking for lowland soils; where farmers have measures of % clay then this can be tightened up; these will give a farmer an accessible tool to allow each of them to understand where they sit in terms of potential (and also wider soil health benchmarks).
- Steve McGrath: See relative impacts of different practices on SOC: Poulton *et al* (2018): Major limitations to achieving "4 per 1,000" increases in soil organic carbon stock in temperate regions: Evidence from long-term experiments at Rothamsted Research, United Kingdom.
- David Powlson: Need to be clear about what we mean by "saturation". Soils under long-term grassland are likely to be at or near saturation. Arable soils are almost always well below this. But the practices that are possible in arable cropping can rarely, if ever, lead to the soil carbon of the same soil under grassland. So, it's not realistic to think that arable soils can achieve "saturation" but rather a realistically achievable level, as explained by Liz Stockdale.

Q: If there is little potential for increasing soil carbon in saturated soils - which are common across the UK - perhaps soil carbon trading or equivalent (or anything that relies on counting it to produce a payment) are less relevant and should be replaced with a more holistic soil 'health' matrix? An adaptation payment if you will?

- David Powlson: I would favour payments for practices likely to improve long term sustainability, recognising that short term benefits for farmers may be small. Soil carbon will be part of this, but not just total quantity of carbon. Small changes can have a big effect.
- Pete Smith: Cropland soils and badly degraded grasslands are not at saturation point so they can increase in soil carbon. There are a lot of these in the UK (particularly croplands) so they offer the greatest potential for additional carbon sequestration.
- Steve McGrath: This is true. See Prout *et al* (2020) What is a good level of soil organic matter? An index based on organic carbon to clay ratio.

Q: I have a question about the form carbon takes in the soil. Is it all equal in terms of sequestration and also in enhancing fertility/yield, water quality etc?

- Pete Smith: There are different forms of soil organic matter - but all provide benefits to soils (if in different ways) - generally speaking, increasing soil organic matter is beneficial (as long as no polluted sources are used).

Q: I'm keen to find out if there are types of soil carbon we should be aiming for as opposed to others. Biochar is stable in the soil for potentially millennia, whereas anoxic archaic plant material (peat) oxidises when dry. Microorganisms respire. Live roots vs plant residues? I feel there is more nuance here than just "increasing SOM".

- Pete Smith: Peat should be left where it is (in peatlands)! Biochar is longest lived carbon - and generally speaking the higher the lignin content and carbon:nitrogen ratio, the lower the decomposability.

Q: How does climate (temperature etc.) affect the ability of grasslands to 1) be grown and protected, and 2) to sequester carbon?

- Pete Smith: Grasslands do better (and store most carbon) in wetter areas on heavier soils.

Q: How much would a system for soil organic carbon monitoring and verification cost to do per hectare?

- Pete Smith: Cost per hectare of verifying soil carbon if done on one farm with measurement and lab analysis can be very high - £100's per hectare - more than the carbon is worth on the carbon markets! But if lots of farms get together and you get a verification set up as I discussed (remote sensing, modelling, activity data), economies of scale and cost sharing could slash costs. This is where we need to go.

Tillage

Q: Zero tillage - is there any merit in periodic ploughing to distribute carbon deeper in the profile? Appreciate that defeats the term zero-tillage!

- Pete Smith: Some experiments in New Zealand show that turning topsoil deep under stores more carbon - so opposite of zero tillage - it is more like uber-tillage!!
- David Powlson: Many people think this deep tillage idea is very risky. Risk of increased carbon decomposition due to great disturbance.
- Pete Smith: Agree, David. And it leaves you farming in low organic matter subsoil. Likely bad for productivity...
- Liz Stockdale: Note that the NZ example is of a podzol (high OM not well mixed overlying very poor sand) and the approach relies on effective full-inversion and very little disturbance of the OM .... so another of those "it depends" - works in a very few places

Q: Can zero-till increase N2O on heavy soils that could compact?

- Steve McGrath: Yes, there is evidence of this.
- Pete Smith: Yes - some evidence that no till on heavy soils can increase N2O. Can reduce N2O on lighter / drier soils though. See here for a review and meta-analysis.

GHG balance

Q: Since grassland is important for carbon sequestration but livestock emits methane, what is the balance between the two? The message from government is that we all should stop eating meat, yet this appears contrary to what is said here?

- Pete Smith: Grasslands have high carbon stocks, but they are at, or close to, saturation - which means that there is no net removal of CO2 from the atmosphere. So, the

"grassland soil carbon sinks cancel out the methane emissions from cattle" argument doesn't really hold water...

- Prysor Williams: This is a really important point, that receives too little discussion when we talk about re-introducing livestock into arable systems for the purposes of improving soils. If we increase livestock numbers dramatically to graze all the grass we may have in the future on arable land, then the balance (pros/cons) in terms of GHG emissions need to be considered. But if there are ways to integrate arable land into existing ruminant systems better, then that could offer other benefits (e.g. reducing the need for concentrates).
- David Powlson: Good point. Don't want increased animal numbers. Nor risk of ploughing old grassland to bring it into mixed system.

Q: Is there a risk of off-shoring environmental impacts if UK degraded arable soils are converted to grassland in an attempt to increase SOC but those crops are still required?

- Pete Smith: Yes - we shouldn't do that - we can increase soil carbon while still using them for cropping (cover crops, improved rotation, residue returns, reduced tillage intensity etc.)
- Prysor Williams: Definitely. This is why short-term thinking and just focusing on our own targets is dangerous. To be fair, this point is often acknowledged by policy-makers (but not always!). Off-shoring our carbon (and any other environmental impacts of food production) is not the way we need to go.

Q: I'm struggling with all this chat about converting arable soils to grassland. Ruminants appear in much of the climate literature to be climate enemy no. 1, mainly due to the way methane is treated, so what on earth is going to eat all this grass? CCC is recommending significantly reduced meat production.

- Pete Smith: Nobody is proposing this.
- Prysor Williams: See earlier point on this - how to better join up arable systems with livestock is key (so being mutually beneficial to livestock and arable sectors), but of course there are practical barriers to this (e.g. haulage / distance issues; the lack of livestock skills in arable systems, etc. etc.) - all important.
- Attendee: There are many organisations and individuals suggesting re-introducing livestock to rotations. The benefits in terms of soil carbon seem fairly obvious, however I'm suggesting there is very little demand for this extra grazing.

Q: Could arable land currently used to grow feed for ruminants be converted to grassland for feeding that livestock?

- Pete Smith: That would be a dumb thing to do!
- Attendee: Surely better to have arable land currently used to grow feed for livestock to increasingly be used to grow food for human consumption (in climate terms)?

Q: Do we know what % these degraded soils are of total agricultural land?

- Steve McGrath: About 40% of arable soils in England and Wales. See Prout evidence.
- Liz Stockdale: Also to note that there is significant variation between arable soils - some higher OM as a result of different management but still economically viable arable production - so part of the development of best practice as per AHDB monitor farms and Farming Connect is peer-benchmarking and on-farm demonstration.

Q: So from what I understand, outdoor pigs on an established grass ley (paddocks split to ensure half is rested and allowed to regenerate), and then the muck/straw produced throughout the two year occupancy spread and incorporated afterwards should be fairly beneficial wrt increasing soil carbon?

- Pete Smith: If the soil is depleted in soil carbon, this management could be good for soil carbon, but grasslands tend to be at or close to saturation, so there may be no/minimal impact on increasing soil carbon. Accounting for other greenhouse gases (e.g. nitrous oxide

and methane from the manure) this system is likely to be a net contributor to climate change - but indoor pigs are too...

Other benefits

Q: Increases in SOC and productivity - what do the figures look like in UK temperate climate soils?

- Pete Smith: Not much productivity increase for UK as soils tend to be relatively well-managed already - only poorly managed soils will benefit.

Q: If you increase soil health and quality what does that equate to in terms of water infiltration capacity, as a potential ecosystem service? Tonnes of water per hectare?

- David Powlson: Water etc. Cannot give numbers - others will have that. But better structured soil allows greater infiltration - good for crops and flood control.
- Steve McGrath: The work of Andrew Neal at Rothamsted shows that increased SOC increases the number of connected pores in soil and decreases N2O emissions.

Biochar

Q: Biochar, what proportion of increased carbon stock is due to the added carbon (i.e. movement from one pool to another) and what is additional sequestered carbon?

- David Powlson: I am very cautious concerning biochar. First, because I cannot see how it can be used at large scale. Where will the organic material to make it come from? Municipal waste currently put into landfill is one option – I don't know the quantities available, but I think not huge. If it is proposed to grow large areas of (say) fast growing trees for biochar production, this use of land competes with food production and other land uses. Second, it is unlikely that biochar will improve soil functioning in the same way as more decomposable organic matter that provides energy for microbes? The literature on biochar effects on soil properties is very mixed – observed benefits are often limited or in very special situations. Third, if the main benefit of biochar is simply to lock up carbon, why bother adding it to soil? Just keep it in a heap!
- Jonathan Scurlock: Biochar, as a relatively inert form of carbon potentially used as a novel soil amendment, would be an independent pool of stored carbon distinct from soil organic matter, although it may form complexes with it due to its microporous structure. Once biochar has been produced, by pyrolysis of biomass (organic matter), it is thought to be very stable when landspread on soils, with a turnover time measured in centuries. Large-scale field trials on a variety of UK soil types are just commencing to investigate whether this can be realised at scale and how its performance varies as a function of parent material, the pyrolysis process, and prevailing soil conditions. These trials will also evaluate potential interactions (positive or negative) with soil flora and fauna, soil function and fertility, and rates of organic matter turnover.

Unanswered questions/comments

- Is increasing soil carbon in upland farms by 1% compatible with the high carbon levels?
- Do e.g. suberin, peat, biochar, lignin, exudates, glomalin, and living organisms all behave differently?
- Drainage very important part of the process.
- How do we get better understanding of the difference between maintaining existing stocks and opportunities for additionality? How do we also promote the value of maintaining what we've already got rather than run the risk of ploughing up and starting from scratch?
- We've seen widely different estimates of mitigation potential for UK (non-peat) soils. What do you think is a realistic range of mitigation opportunity for UK arable and/or grasslands?