Matthew Warnken:

Well hello, everybody, and welcome. Welcome to our fifth episode of AgriProve's webinar series on how to grow top soils. My name is Matthew Warnken. I'm managing director of AgriProve. I'd like to start by acknowledging the traditional custodians on the land where we may be viewing this webinar, pay our respects to their elders past, present, and emerging. Now, AgriProve is a soil carbon product developer. We're looking to enable landholder participation in carbon and other environmental markets to create the potential for farmers to access additional forms of revenue.

Matthew Warnken:

We're hosting this seven part series. Very fortunate to have Declan McDonald, principal soil scientist with Regen Soils, here to really unpack that journey on how to improve soil health and how to grow soil carbon. Declan is a certified professional soil scientist. Over 30 years experience in soil and agriculture amongst a variety of public and private roles in that public/private sector. And if you've been tuning in to any of the past four webinars, you'll see just that unique insight that Declan's able to bring to bear in terms of how to grow soil carbon from that wealth of experience.

Matthew Warnken:

Now, so far with the previous webinars we've looked at how soil works, how plants grow, organic matter, soil biology. The last webinar was on mineral management, the role of macro and micro elements, and that really honed in on just the importance of soil testing, but not only getting the soil test, but how to decipher those results, the importance of balancing mineral content. And again, some great concepts, some great visual concepts like that ball of string graph in Mulder's chart, the concept of the sponge, the view of the Harbor Bridge, the rainbow nitrogen graph, which I recommend everyone goes and looks back at episode four to find that. But also some challenging stats, and Declan, you can correct me if I'm wrong, but that ratio of one third of fertilizer application in terms of corn crops in the states having to be applied just to account for that loss of soil function, and then contrasting that with approach in terms of how much fertilizer can we put on, but how little fertilizer we should actually be applying, and stand to unpack some of those formulation and application pathways such as liquid foliars.

Matthew Warnken:

So, look, this webinar is on managing fertility to build soil carbon. Before we get into it, again, some housekeeping. We are recording the webinars. They are available on our website, so you can catch up if you do miss a session. Each session runs for about an hour. Declan will be speaking for 40 minutes, and we'll have question time at the end. We are also streaming on YouTube live. Now, there's a chat panel on YouTube, a live for questions or comments. If you're tuning in on Zoom, you'll notice a Q and A as well and a comments function, so please feel free to ask any questions throughout the webinar. And also, if you're tuning in after the actual broadcast date, feel free to send an email to the team and we'll be happy to pick up some of those questions.

Matthew Warnken:

So, I'd like to hand over now to Declan McDonald, and look forward to this installment of how to grow top soils. Thanks, Declan.

Declan McDonald:

Thanks, Matthew. My 'share screen' option doesn't seem to be working which is a bit of a problem. So, what I might do is while we're just waiting to see if we can load that up, there's a few questions that came out of last week which I might go to. One of the questions that was presented, that came through last week, and these were follow up questions again for after the webinar, was when I was talking about soil test results and we were talking about presenting information, the way that information is presented on soil tests often showing many different units and whether the elements were soluble or exchangeable.

Declan McDonald:

The question was asked, "Why present the same information with different testing types?" Look, they're all just giving us slightly different insights into the information presented. So, I mentioned with the cations in particular, calcium, magnesium, etc., that they function both as essential plant elements, but also have a really significant role in soil structural properties. So, presenting them in those different ways gives us insight into availability for plant growth, and also gives us an insight into how they're influencing soil structure.

Declan McDonald:

The next question asked if I had a rule of thumb on nutrient use efficiency and cost. Well, there's not really a rule of thumb. The only rule of thumb is increase nutrient use efficiency as much as possible because obviously, anything less than 100% is costing you money, so if we only have a nutrient use efficiency... If we only have a nitrogen use efficiency of 45%, for example, it means more than half of the nitrogen that we're purchasing is going somewhere other than into a plant and contributing to our profit. So, the rule of thumb really is to understand your nutrient use efficiency, and in fact, the tool that I used for that is quite a sophisticated spreadsheet that was developed by, well, what are called now Department of Ag out of Ellinbank. And that's available online for any of you to use, so I'd encourage you to get stuck into that and figure out what your respective nutrient use efficiencies are as a guide to whether your management practices are improving performance or not.

Declan McDonald:

How are we going, Matthew? Are we ready to go, or will I keep going with questions?

Matthew Warnken:

Yeah. So, we've got the power points. That should work, and if that doesn't work in two seconds... Here we go, but you need to be in presenter view. Yep. Like that. That's good. So, maybe just shout out, Declan, when you want to go onto a next slide.

Declan McDonald:

Will do. Okay. Thanks very much. Okay, so what I want to talk about today is managing fertility to build soil carbon. So, soil carbon is really what it's all about. It's the cornerstone, as I've said before, of soil health. So, we just need to get clear about where soil carbon fits into the picture and really how we manage soil carbon, how we manage this kind of complex element that is not... We're not able to exert the same control over soil carbon, soil organic matter, as we can over, say, a bag of urea. So, we need to understand better how it works, and in so doing, give us improved control over its management. So, next slide please.

Declan McDonald:

So, you'll recall we talked before about the makeup of soil, air, water, mineral particles, and the smaller organic fraction. So, the mineral particles, when we apply fertilizer we're adding to that mineral particle pool. Next slide. So, the difference between mineral and organic fractions, we talked about this also previously, minerals being the non-organic component of the soil, and these are the things that are coming out of rocks, essentially, and your natural deposits over time, such as lime deposits and gypsum deposits and the like. And organic fertilizers came from something once living. And it's important to understand that nature specializes in what are called organo-mineral bonds, so that's the connecting of the organic fraction with the mineral fraction to perform a whole range of functions, nutrient uptake, soil structure, and then within plants and microorganisms themselves. Next slide.

Declan McDonald:

So, when we talk about what drives soil fertility, the simple answer is minerals. And I think the simplicity of this idea is what helped, I guess, modern agriculture, and if we call it chemical agriculture, to take off, because agriculture post the Second World War became dominated by chemicals. Liebig, I think, was German, a scientist from 100 odd years ago, and he developed this concept of the most limiting factor. So, he identified that there is a number of essential macro and micro elements, and that productivity is constrained by whatever is the most limiting of those essential elements.

Declan McDonald:

So, as you can see here, the barrel is a really good illustration of that. In this instance water is the limiting factor, but if nitrogen was the lowest stave, it doesn't really matter how high phosphorous or magnesium or calcium or anything else is. The whole production system is going to be limited by that limiting factor. And so, the theory is that all macro and micro elements must be present in appropriate proportions for plant growth to be optimized. And a lot of agriculture and horticulture has really developed strongly around this concept, and part of the reason for that is that in many respects it really put the control of fertility into our hands, where we could manage deficiencies really very simply through application of an appropriate fertilizer to address that deficiency, and thereby raise that lowest stave and increase the productive potential of our paddocks. Next slide.

Declan McDonald:

So, when we think about the formulations that plants need, in other words, we throw on a bag of super. How does that get into a plant? How does that influence plant growth? Well, there's certain formulations that plants require to be able to take these elements up. So, if we apply nitrogen, we need to apply nitrogen either in the nitrate or ammonium form, or in forms that will convert to nitrates and ammonium. I'm generalizing a little bit here because if we apply urea, plants can take up a certain amount of urea in an unamended form, but most of the urea will get converted to ammonium and nitrates before plants take it up. Sulfur is taken up in the sulfate form. Phosphorous is taken up in the orthophosphate form, and there's a couple of different ionic forms of orthophosphates. And mineral ions, so the potassium, calcium, magnesium, and trace elements of zinc, copper, manganese, boron, are all taken up in ionic form.

Declan McDonald:

Now, it's important to point out that plants also take up whole amino acids. Just click forward for me please. And amino acids are essentially building blocks of proteins, and this is a classic amino acid structure. There's 20 odd, 21 amino acids that exist in the world, and these are generally essential, certainly for us mammals. They essentially all have this core structure of the amino group, the carboxyl group, and the central atoms of carbon and hydrogen. The R-group, the side chain, is what differentiates each amino acid from each other. But essentially, the amino acid contains carbon, hydrogen, nitrogen, oxygen, all elements that the plant needs for its function. So, in taking up amino acids, it's a very efficient way for plants to take up... And when we talk about efficiency, we're talking about the amount of energy that's required for the plant to take up and access nutrients in these forms. And amino acids are available in a highly organic medium. Next slide, please.

Declan McDonald:

How do plants access nutrients to grow? Well, they access them via organic matter and/or mineralization from rocks. We talked a lot about the microbial bridges that are involved in that process, is from a bag, and this is our love affair with kind of the instant results that we've gotten from a bag has, as we've discussed, compromised the soil function. Next slide.

Declan McDonald:

Now, we talked about this briefly, and I'm just touching on it again. So, we're talking about nutrients and soil organic matter. Just highlighting that we're looking here at soil organic matter and the fact that we've got fixed components of elements in really all life forms, not least of which is humus. Next slide.

Declan McDonald:

So, we've talked about the fixed ratios of humus. So, 10 parts of carbon has got 0.8% nitrogen, phosphorous, sulfur, and therefore, to sequester 10 tons of carbon in soil organic matter, I need to make sure that that much nitrogen, phosphorus, and sulfur is available. This is some work that CSIRO did a few years ago. It kind of frightened people a bit at the time because the implication was, "Oh my god. I'm going to have to put on 830 kilos of nitrogen and that's going to cost me a fortune." That's not the case, and they weren't trying to say that these additional nutrients have to be applied, but it does mean that there is a balancing act that needs to be managed. Next slide.

Declan McDonald:

So, we do need to understand that the supply of nitrogen, phosphorous, sulfur, and not just carbon can limit the formation of humus. So, when we look to see where these minerals come from, we know from our previous discussions that we've got lots of nitrogen-fixing organisms in the soil, and they're kind of collectively known as dizazotrophes, and that includes the rhizobium that we're familiar with in legumes and other azotobacters that might be free-living nitrogen-fixing organisms in soil. We know we have a wealth of P solubilising organisms in the soil.

Declan McDonald:

And the mineral resources of the soil, so we're talking about the mineral component of the soil, as that continues to weather, it continues to give up nutrients from that ancient source, and that's very much the role of soil organisms and very much the role of fungi to extract elements from the mineral component for the soil. And we're talking here, particularly, about potassium and trace elements, and both of these can also come from the organic fraction of the soil. So, nutrient cycling through that organic fraction is what keeps these nutrients flowing and keeps these nutrients cycling. But today, I wanted to highlight the importance of one of the organic matter pools that we previously discussed, the particulate organic matter or the labile pool to nutrient supply. Next slide.

Declan McDonald:

Now, this was a bit of a reminder. Just give me three quick clicks. We looked at this previously, but I'm putting it up to remind us all that the purple line is showing that soil carbon storage capacity is finite for each soil type, and we talked about that. The clay content is a really significant influence on the amount of carbon that any soil can hold, and that changes in carbon take place over long periods of time. You can see in the initial phases of manure application, soil organic carbon is rising relatively quickly, but that capping off, that kind of absolutely filling of the bucket starts to level off after a period, and will continue to fill to a point, but it takes a really long time to get the last, if you like, five percent.

Declan McDonald:

But any changes that we commit to to build soil carbon have to be maintained to ensure that soil carbon continues to increase, and what the blue line is showing is what happened when the manure additions that commenced back in the 1850s stopped, and we see a gradual decline then as that material runs down. And one of the key messages that I would like people to come away from this series is really about the importance of sticking to the plan of understanding that soils need to eat every year, not just once, and we need to maintain a high input of soil organic matter to sustain high levels of soil function. So, next slide please.

Declan McDonald:

So, just reminding you briefly, we have principally three pools of organic matter that are defined mainly by their residence time in soil. So, the labile, the particulate organic carbon form of soil organic matter, it says here one to five years, but actually, it can be a matter of weeks and up to five years. The slow pool is also referred to as humus, and certainly humus can also last longer than 40 years. And then, the resistant organic carbon pool certainly lasts the longest. So, I want to focus in on the labile pool today, as a pool that is most responsive to our management and most influenced by our management. Next slide.

Declan McDonald:

The point I wanted to make here was this diagram, and I'm not sure if I shared this one with you before. It's a little bit confusing, but on the x-axis down the bottom we've got CEC, soil structure, energy for biological processes, provision of nutrients, and soil thermal properties. So, these are all things that organic matter influences, but the different pools of organic matter, the different type of organic matter, are weighted differently across this spectrum.

Declan McDonald:

So, for example, CEC really depends on humus and recalcitrant carbon. The particulate carbon does not really do very much for cation exchange capacity. But the green of the particulate carbon shows that, excuse me, it is significant in soil structure, but it's particularly significant in terms of energy for biological processes. So, that's because this is a less protected form of organic matter. It's more freely available to soil microbes, so they're well adapted to get stuck into this and to extract maximum energy from it. Similarly with humus, and we can probably thank the fungi here because they're more adapted to extracting nutrients from more recalcitrant forms of carbon in the soil, and humus is a more recalcitrant form than particulate, so it is still a significant pool of nutrient for biological processes, both for plants and for soil organisms. Next slide.

Declan McDonald:

So, I'm going to step you through here. These slides came from Jeff Baldock, who's our national soil carbon guru, and this was some modeled data that is illustrating the impact of land management practices and the impact of those practices on the different carbon pools. So, in this particular example, we have a paddock that was converted from pasture to cropping at year 0, and after 33 years we see a steady step decline of organic matter. And each one of these kind of steps would coincide with either some kind of tillage operation or some kind of cultivation where we have a shorter acceleration of organic carbon loss. So, at year 33 the system is converted back to permanent pasture. Click once, please. So, what this is showing is that the organic carbon level at year 15, it takes 18 years to drop to its lowest point, but then if we're just measuring soil carbon it shows in 10 years we've bounced back. Well, we should be fairly encouraged by that, but we need to look a little bit further into this story. Next click, please.

Declan McDonald:

And when we look at the humus, we see that the humus is contributing to that rise, but it doesn't represent the full extent of that rise. In fact, you can see that humus is rising much more slowly, and in fact, after a modeled 75-odd or 80 years, it's still not up to where it was 18 years ahead of returning the soil to pasture, and it's certainly nowhere near where it was at year 0. Another click, please.

Declan McDonald:

This is the particulate organic carbon, and you can see that it ran down quite quickly in the first five years, but it has bounced up very quickly in the following 10 years, almost to its full level. And so, that's telling us that it's the particulate organic matter that's contributing most to the sudden rise in soil organic matter. One more click. And this is the recalcitrant or inert organic carbon, and you can see that that hasn't really moved at all. Next slide. One more click too, please. So, we're seeing that there's 30% less humus in this equation, but 800% more particulate carbon over this period.

Declan McDonald:

Now, if we see what happens after this period, so after a further 10 years if we decide we're going to go back into cropping again... We see that we have the same precipitous decline again which is reflected in the particulate organic matter, and humus continues its long and sorry decline back to very low levels. So, we can predict from our previous discussions just how this paddock is performing, how this paddock is yielding, and if we were to do a soil structure score on this, what that score might be, and as a result, just how much extra fertilizer we might be having to put onto this paddock to get the same level of production that we were getting, say, between years 15 and 33 when it was well into its cropping phase.

Declan McDonald:

Okay. This was some separate work that was done also by Clive Kirkby of CSIRO, and they looked at virgin soil that was never farmed, never fertilized, and these are New South Wales soils, that had a soil organic carbon level of 3.5, long term pasture 3.9, and long term cropping of 2.1. They were able to remove, basically burn off the particulate organic matter to see what remains, and the virgin soil with the particulate organic matter removed is at 2.1% soil organic carbon. So, this is showing us that a really significant proportion of that three and a half percent organic carbon in the virgin soil was compromised of particulate carbon. That's the material that's cycling fastest, that's driving biological activity, and that's driving nutrient cycling for plant uptake.

Declan McDonald:

The long term pasture you can see also has a significant drop, not quite as large as the virgin soil, but interestingly, in the cropping sight you can see that there's almost no change, and what that tells us, of course, is that the disturbance and the mono cropping and everything else associated with cropping activities long since burned up the particulate organic matter, the labile carbon, which is... It's like in the days before COVID when we used to have cash. Particulate organic carbon is like cash. It's kind of readily available. It's there in your hip pocket. The humus might be your credit card where you have to make special arrangements and pay that back, and as I said before, your recalcitrant carbon might be the lump of gold that you've got sitting in a bank account somewhere. Next slide.

Declan McDonald:

So, this explains... We shared this graph earlier too. It explains why soil carbon loss is so precipitous in the early stages following clearing, and why soils do settle down to an equilibrium level based on the capacity of the soil to protect the remaining carbon. It also tells us something about the soil carbon sequestration potential. Next slide.

Declan McDonald:

So, this is just a little case study that I thought I'd throw in, and thanks to Peter Ronalds for this. This site is in kind of North Gibbsland, I suppose we'd call it, near South, and it provided a really interesting comparison between a perennial pasture paddock and a potato paddock, separated by only just over 100 meters on the same red soil type. Next slide.

Declan McDonald:

So, what this showed... The top photograph is the potato paddock and the bottom photograph is the pasture paddock, and the potato paddock was in perennial pasture until 2010. It was cropped for one year in 2010, and returned to pasture in 2010. And this sampling was done, I think it was 2017 or thereabouts. So, a number of years later the soil carbon levels in that paddock were 163 tons to the hectare and the top foot 6% carbon. The soil structure, there was a compacted structure with a hard pan at 30 centimeters, and coring to take these samples was difficult, with each core getting stuck in the coring tube. And these red soils, they can be a serious hassle when we're coring because they can be very sticky and just a real pain to get out of the coring tube.

Declan McDonald:

In contrast, the pasture paddock, which I don't know if it had ever been disturbed but certainly a very long time in pasture, its carbon levels were substantially higher. 213 tons compared to 163 per hectare, 10% organic carbon compared to 6%, and the soil structure, crumbly peds with good structure, and the coring was easy. So, the difference between these two soils based on a single potato crop was really what was so startling about this. And bear in mind potatoes are one of the tougher crops because of the amount of cultivation and disturbance, not to mention very high fertilizer levels that usually accompany potato production. So, a really major impact between these two events, and so much of this impact could be attributed to the loss of particulate carbon as a proportion of that total carbon drop. Next slide, please. So, just to kind of recap on this... This particulate carbon is really punching above its weight in terms of that ready availability of energy and nutrients for biological and plant growth. Next slide.

Declan McDonald:

So, just where does the particulate carbon come from? When there's this kind of feed on top of the ground, there's a massive amount of feed below ground. So, when this stock goes through and they eat this off, we have high pasture utilization and we've got a lot of material pushed onto the surface of the soil... Next slide. These are a couple of stills from the video series that we developed last year. We suddenly have all this material both at the surface of the soil and roots and the like sloughing off beneath the soil. And the material that breaks off most quickly and the material that's most readily available is going to be the particulate material.

Declan McDonald:

So, after a big grazing event like this, we really have a massive pulse of carbon going into the soil. A lot of it is going to be readily available. Think of all the root hairs and everything, the massive root hairs on all of these plants. That material is very poorly protected, so that's going to be most available to soil organisms, not to mention the material that's deposited on the surface of the soil, but also in the root systems as well there will be more recalcitrant forms of organic matter which will take much longer to turnover in the soil. But this is very much the way nature designed grassland systems. Next slide.

Declan McDonald:

We talked about nutrient use efficiency, and going back to the modeled data from CSIRO, as I said, when the organic matter is run down that much, and particularly when we lose our particulate carbon, that's where structure really suffers and where potential yield really drops. And the next slide.

Declan McDonald:

And the point here again, and this is a slide that I shared previously too and forgive my repeating some of these points, but I think what I'm trying to do is pull the picture together and remind you of some of these things so that the picture gets filled out. The point here really is that the way that we farm is most important, so although our top three performing farms in this nutrient budgeting trial that I did with Monash Uni a number of years ago, we can see that in the top five there's a couple of conventional farm that are in touch with the leaderboard because they're basically very good farmers. And down towards the bottom, there's somebody who's using compost. But on the basis of their overall ranking and their nutrient use efficiency, even though they're using compost, there's some other things they're not getting quite right because their nutrient use efficiency is still way too low. Next slide.

Declan McDonald:

Okay, so I was going to thin out, and I wanted to... Not sure how we're going for time. I wanted to allow a little bit more time in these closing weeks for question time, because we're really getting to the point here now, "Okay, how are we going to put all of this into practice?" So, I'm encouraging your questions, and next week we're going to be focusing very strongly on management practices to put all this into action. Now, I addressed that question in the lead up, so we'll move on from there, and also the next one.

Declan McDonald:

So, one of the questions was, how would you characterize the difference between soil organic nitrogen and synthetic nitrogen, and my answer in a word is leakiness. You'll recall when we talked about the nitrogen cycle that there are so many lost pathways in the nitrogen cycle that it's very easy to lose nitrogen out of the system. We can lose nitrogen by leaching of nitrates into groundwater. We lose nitrogen by conversion of nitrogen in the soil to N_2, nitrogen gas, and it will drift back into the atmosphere fairly harmlessly, but some nitrogen will get converted to N_2O, nitrous oxide, which is a really bad greenhouse gas 300 times worse than carbon dioxide. So, we really want to avoid nitrous oxide emissions, but they're a real problem in poorly structured, poorly drained wet soils, is the soils that are most vulnerable to nitrous oxide, and a lot of dairy soils fall into that category.

Declan McDonald:

The other way that nitrogen is temporarily lost is through immobilization into the microbial pool. Now, that's not necessarily a bad thing because it just goes into temporary storage, if you like, while it's locked up in the body of a bacterium or a protozoa, but when those organisms die that nitrogen gets turned over again. And these are, if you like, the safer ways. When nitrogen is sequestered in organic forms in the soil like this, at least it's not going to leach and at least it's not going to volatilize off. So, synthetic nitrogen because of the formulations are very prone to losses via these irretrievable pathways that is leaching and volatilization compared to organic nitrogen, which tends to stay bound either in living or dead organic forms. Next slide.

Declan McDonald:

And similar to this, our slow-release applications such as rock phosphate or slow-release urea are better to use if you have to address deficiency with fertilizers. Well, firstly, if you have to address deficiency with fertilizers, apply fertilizers. I am certainly not against fertilizers, and I'm not against mineral fertilizers, but as we've said before, it's the kind of blunt weapon approach to the use of mineral fertilizer that causes these problems. We put on enough fertilizer at the start of a season maybe to last the whole season, well, we're dealing with a feast and a famine. The soil and everything in it is often not able to process the amount that we put on. Some of it escapes those organic immobilization processes and ends up causing damage further down the chain.

Declan McDonald:

But certainly, use slow-release forms such as rock phosphate or urea, provided... And it's something to do gradually rather than... Again, no sudden movements as far as the soil is concerned because the soil is a bit like the rumen of an animal. It takes some time to adjust. So, if you suddenly go from highly soluble available fertilizers to slow-release, the mechanisms in the soil have not yet built up to be able to unlock those elements quickly enough for you, and you'll have a period of declined production as a result. So, blend these. Continue using a soluble but blend it with a more stable and slow-release form of fertilizer, and take three years or longer to transition through to a slower release form. And then rock phosphate is a case in point, but something like slow-release urea is generally urea with additional coatings on it or, say, with humate supplied to slow the release. So, that's not quite as slow as rock phosphate, so slow ain't slow. Next slide.

Declan McDonald:

Are there optimal ratios for organic matter to calcium to magnesium for building soil structure? So, you'll recall last week we talked about the calcium magnesium ratio and the importance of it for soil structure. Organic matter really just trumps everything, so there aren't optimal ratios for organic matter to calcium. Basically the more of it, the better, in simple terms. That was just the graphic that we talked to last week. Next slide.

Declan McDonald:

The importance of soil structure at depth, and how does this impact the growing zone. I think that picture tells a thousand words. On the right-hand side we have no structure to depth, and we've got water logging, we've got poor root development, we've got a crop that's vulnerable to drought, we've got very poor biological activity, and we've certainly got no access to deep water, no conditioning of soil structure to depth. So, soil structure to depth, incredibly important, and we can only manage that with either growing deep rooted crops or incorporating a mix of deep rooted crops and shallow rooted crops. Next slide.

Declan McDonald:

How do soil microbiological communities impact on making nutrients available for building soil structure? Just click on for me here. And again, calcium and magnesium, these are some of the really important roles. So, it's not just calcium and magnesium. It's a whole system that's at work here developing soil structure, and calcium and magnesium, as I said, wear multiple hats in the soil and at the availability of... Microbes are hunting for those because these are macro elements that microbes and plants need a lot of as well. So, the machinery in the soil to extract and to cycle the nutrients is as focused on calcium/magnesium as it is on any other element. Next slide.

Declan McDonald:

What tests are available to show how well the carbon building process is going on in our soil, and can they indicate what parts of the process needs to be tweaked? Well, yes, but in simple terms there's three main types of testing for soil carbon. The potassium permanganate oxidation test tells us how much particulate organic matter is in the soil. So, we've talked about that labile fraction, that very reactive fraction, so if we want to understand what proportion of our organic matter is labile, we'll do a potassium permanganate test in conjunction with a Walkley-Black or Leco/Dumas combustion test, which gives us... Both Walkley-Black and Leco or Dumas test tells us what our total organic carbon is. So, we would need to do a potassium permanganate at the same time to separate out the labile from the humus and recalcitrant. There is a test available to separate out the humus fraction as well, but it's a very messy, expensive, and slightly inaccurate test, so I wouldn't recommend it. I think it's more important to know what your particulate component is rather than trying to separate out your humus from your recalcitrant.

Declan McDonald:

And of course, there's microbial testing that can be done as well, and microbial biomass testing is a kind of simple, cheap, but not very detailed measure of the total microbial population in your soil. So, what is the weight of microbes in my soil? The PLFA method is a phospholipid fatty acid array, and it is carried out by Microlabs in South Australia. It's a much more detailed analysis of some of the primary types of organisms in the soil, so it'll separate out bacteria and fungi and mycorrhizal fungi, and also give a figure for microbial biomass. And then there's genomic testing, but that's not really commercially available as yet. That's still very much in the research realm, but we look forward to that in the coming years. Next slide.

Declan McDonald:

What is the role of fulvic acid in improving nutrient use efficiency, and what's the effect of compost tea compared to compost and impact on nutrition? So, there's lots of stimulants and activators on the market, and I say caveat emptor to that. Just be careful because a lot of the products don't live up to the hype. Sometimes they do, and one of the kind of perplexing things about this is it's not always clear why they might work on one particular farm and not work on another. And in discussion with soil ecologists and microbiologists, we kind of understand that if there's an available ecological niche in the soil and we fill it with a compost tea, for example, or with a stimulant, we will see a really good response, but if that niche is not available or if all the niches in the soil are already filled by more competitive and adapted local micro organisms, they'll have the compost tea for breakfast.

Declan McDonald:

Fulvic acid is... Effectively, it's a chelator. It's also a carbon source, and it's a bacterial food so they'll access that very quickly, but I think the real value of fulvic acid is if we're foliar feeding and we're applying it with fulvic acid. Fulvic acid will contribute significantly to the efficiency of plant uptake. Another point about compost tea is it does introduce novel organisms, but like I say, if there's no niche for those in the soil they'll just get gobbled up. But compost introduces novel organisms plus substrate, so it introduces a lot of energy, a lot of food into the soil. So, even if the novel organisms get munched up by the native organisms, the native organisms are going to get stuck into the compost as a valuable energy source. And part of the question, is the nutrient contribution of whatever you're adding significant? So, are we looking for a fertilizer response or are we looking for a soil conditioning response? Next slide.

Declan McDonald:

Yeah, okay in summary. So, managing fertility is about creating a soil environment for everything that will live in the soil, micro and macro organisms and plant roots. Relying on urea and superphosphate to grow pastures and crops is not creating an agroecosystem. It's just force feeding. And managing fertility has always been about organic matter. Organic matter buffers pH and salinity and facilitates de-toxification of soils. Next one. It's got a central role in soil structure, which we talked about, the ventilation and drainage system in soils. One more. And it's the primary energy source in soils. And finally, you'll not go broke from having too much organic matter.

Declan McDonald:

I'll just go onto the next one briefly. So, this is what we've worked through, and like I said, I've been trying to build a picture for you over the five weeks that we've traveled so far, and next week we really want to focus on applying all of this learning into grazing, cropping, and perennial systems, and we'll talk very much about management practices here. So, if you do have questions that are particularly relevant to your farm, send them in during the week and we'll see if we can include them next week. Okay. Back to you, Matthew.

Matthew Warnken:

Great. Just working out how to unmute myself. Thank you very much, Declan. Again, a fascinating insight in terms of those various complexities, in terms of what's going on with soil carbon, and I guess those challenges that we can't control soil carbon as easy as a bag of urea, so really do need to understand it in much greater depth. And then, picking up that recurrent theme that this is a long-term activity change and management change, and again, that importance of no sudden jolts.

Matthew Warnken:

The different soil carbon pools, I thought that was a fascinating take on just soil organic carbon. Soil carbon isn't just soil carbon, so it's pools. The labile, the particulate organic matter, the resistant and recalcitrant soil carbon pools. Did make me question about your relationship with your bank manager though, Declan, in terms of the lumps of gold that you obviously have stored away in some vault as the recalcitrant cash reserves, but then credit card being that humus resistant pool, and obviously, that sort of immediate cash reserve, and you'll never go broke if you have that more labile particulate organic matter.

Matthew Warnken:

I did think it was a really interesting take, that management seemed to shift particulate organic matter much sooner than, say, those other pools, and also the characterizing cropping systems as being really, really deficient in that particular organic matter was, again, fascinating. That concept too of the Liebig's barrel in terms of where your overall productivity constraint might be in terms of that limiting factor, that lowest stave in terms of on the barrel, I thought that was great. And also, great to pick up some of those Q and As on those questions come through from past episodes.

Matthew Warnken:

Maybe just focusing on Liebig's barrel in terms of picking up some of the questions from this episode, do you think you could do a Liebig barrel assessment on a farm, like an actual more holistic assessment as to what the limiting factor on a particular farm would be for productivity?

Declan McDonald:

Yes. We've talked a lot over the last few weeks about nutrition, both in the mineral form and organic form, and we've also talked about soil structure. We probably haven't talked about that quite so much, but I think the point has been made that when we talk about soil structure, we're really talking about the ventilation and drainage system. And if you think of your soil, and if you have a meter of soil, you might only have four or six inches or twelve inches of top soil, but you've got a lot of soil underneath that, and we tend not to think about that at all because often it's a little bit hostile. It's maybe very high clay, and we think it's not contributing too much to the productivity of the exercise because with modern agriculture we've been forced to think about the top four inches, the top 10 centimeters, and we're feeding that top 10 centimeters.

Declan McDonald:

And I think for me, the problem with Liebig's barrel is it just puts all that focus on, "These are the essential elements that you have to have, and it's very easy to replenish any deficiencies out of a bag. Problem solved." That's feeding the plant. We really need to shift. If we're going to manage the system holistically, if we're going to think about all of those things like soil structure, rooting to depth, accessing your deep water, promoting biological activity, sequestering carbon to depth in the soil, that's where we have to think about, "What do the workers in the soil need to grow my crop for me?"

Declan McDonald:

And if we think of it from that point of view, yes, there may be a nutrient deficiency in the soil. Well, let's supply that nutrient deficiency in a way that feeds the soil microbes, in a way that allows the soil microbes to feed the plant. So, it's a little bit like a factory suddenly saying, "Oh, we've run out of ball bearings, so we can't make the machine." So, do you just dump a whole pile of ball bearings in through the roof, or do you give them to the workers at the rate that they're able to utilize them and put them into the machine? It's as simple as that, but it is such a kind of major shift in our thinking that I think we still struggle with it, which is why I repeat myself a bit.

Matthew Warnken:

We need a more intelligent sort of biological pathway to rebuilding that barrel. Declan, we want to pick up some of those other things that you touched on. The soil carbon saturation point, so maybe just to pick our luck on that Rothamsted study. That did show that increase in soil carbon. I did some rough calculations. That was worth about 125 credits under the Emissions Reduction Fund, so it was an eligible project. Over $1500 worth of value per hectare. But the question I guess would be, well, in that which showed that saturation point, is just what's your thoughts on a deepening of the soil profile? So, obviously, that measurement was just at a fixed depth, and I don't know what that depth was, but nature is not linear, so that depth mile then might be saturated at that point. Does the soil profile actually potentially deepen, in which case if you're looking at a deeper horizon a meter and even deeper in terms of that assessment, what do you think might be happening there?

Declan McDonald:

Well, I think the working profile is certainly deepening. So, the example I gave before that you might have a meter of soil but the bottom seven or eight hundred millimeters might not really feature in your thinking in terms of how it supports the productive enterprise. But if we're managing in such a way that we're sequestering high levels of carbon like that, the only place we're sequestering them and the only way we're able to sequester high levels of carbon life out is by bringing those lower parts of the soil profile into much more active part of the production. So, in effect, we will be deepening the top soil.

Declan McDonald:

I was doing a field day for the Mornington Peninsula Vignerons a few weeks back actually, and we had a couple of pits on vineyards. One was a really well performing part of the vineyard. Another was a poorly performing part of the vineyard. And they said, "Okay, we'll put a couple of pits in here because we don't really know why this part of the vineyard is performing so poorly. Same inputs." Blah, blah, blah. Well, it was a no brainer when we opened up the pit, because we could clearly see that the top soil depth on the poorly performing part of the vineyard was half that of the other part. So, the relationship between top soil depth and productivity, it's linear, it's proven, it's really, really significant. So, the smallest extent to which you can increase top soil depth, the rewards are going to be really significant. So, when it comes to a focus on sequestering carbon, the kinds of things we have to do to sequester carbon will increase top soil depth and the functionality of that top soil.

Matthew Warnken:

And with that example, looking at manure application, do you think it was the nutrient elements in the manure, or was it the microbiology that was responsible for the sort of greater increases in soil organic carbon? I guess this is going back to, I think, two episodes ago. We were looking at microbial necromasses being two thirds of the soil organic carbon pool.

Declan McDonald:

Yeah. It's never one thing or the other, Matthew. It's always both. So, the nutrients that are in that manure are contributing to the energy supply in that soil. Those nutrients are helping the soil population to expand. It's like when the economy is doing really well. There's lots of nutrients there. There's lots of nutrients going around. It's why in Melbourne, for example, we've had this huge kind of immigration rate because the population's been expanding because the economy has allowed it to expand. So, the same in soil. If we have enough energy going into that system to allow the population to expand, then not only have we got more nutrients to drive production and to increase organic matter, but all those changes in soil properties that we've been talking about will also occur.

Matthew Warnken:

So, talking about nutrients, spent a bit of time going through the nitrogen cycle today, and picking up on that characteristic difference between, say, soil organic nitrogen or fixing nitrogen and synthetic nitrogen and leakiness, and so fixing nitrogen being more effective because it's not leaky. Could you hazard as a rule of thumb if you had one ton of fixed soil, organic nitrogen, what that might be equivalent to in terms of bags of N that you'd have to apply? Any thoughts as to what that leakiness factor might be?

Declan McDonald:

Well, I would say that if you had a ton of soil organic nitrogen which is cycling through organic forms and being delivered to the plant in a just in time way via those microbial intercessors, the leakiness of that system is really low, because all the mechanisms are there to mop up and mop up quickly any excess. But if we're applying a ton of nitrogen or a ton of urea, which I've come across one dairy farmer that was applying that much per annum, the nutrient use efficiency on that farm would be appallingly low. And I'm happy to say that he's not applying a ton of urea anymore, because that system is being managed so much better now.

Matthew Warnken:

And maybe just if you could remind us again, that nutrient efficiency tool, speaking nutrients, where is that available at?

Declan McDonald:

I'll dig up a link to it, but if someone wants to search Ellinbank nutrient budgeting tool, it should pop up in a Google search.

Matthew Warnken:

Just to fire a few quick ones to finish off on, Declan, could you remind us what a chelator is?

Declan McDonald:

So, a chelator is a molecular structure that will grab the particular element that we want and will facilitate its passage through a cell membrane, usually. So, elements are taken up into cells via kind of lock and key mechanisms, and the key's got to fit the lock or it doesn't get in, but fulvic acid is like the master key that is able to transfer elements across membranes much more efficiently.

Matthew Warnken:

Great. And then, thoughts on the role of trees in, say, soil organic carbon and retaining nutrients on farms?

Declan McDonald:

Well, look, trees of course have got the supremely large root architectures compared to a lot of what we might be growing for productive purposes in terms of pastures or crops on farms. Trees themselves will sequester large amounts of carbon in their standing biomass. But also, because tree roots will generally extend to considerable depths in soil, appropriate tree selection and soil type not withstanding, trees are great to mop up leaching nutrients and to open up pathways in the soil for other roots to follow as roots die back and change over time. So, trees are really valuable, and that's where in reconfiguring our agricultural designs if we can use trees... They don't necessarily have to be giant eucalypts. There was a lot of interest in things like tagasaste for many years, which is basically a large fodder shrub, small tree. Even the use of plants like that in alley plantings as stock fodder or shelter or whatever else, they all contribute really important roles in an agroecosystem.

Matthew Warnken:

Great. And also getting some feedback that it's a journey to build up the soil and then understanding how it functions so you can intelligently apply those additional products, and really confirming just the pathway in terms of basing our understanding of soil function as a pathway to productivity. So, we've gone a bit over time, Declan, but we'll wrap it up there. Thanks, everyone who has been on this webinar, for bearing with us with that technical challenge at the start of this episode. You have been watching episode number five on how to grow top soils. The science of soil carbon. This was managing fertility to build soil carbon. Thanks to Steven and to Mel for helping out just on that technical start and pulling that webinar together. Declan, once again, a very big thanks to Declan McDonald from Regen Soils for his presentation.

Matthew Warnken:

Next week's topic I think is going to be a cracker, management practices to grow soil carbon. I think this is where we're really starting to go from that great understanding of soil function to, "Okay, well, now what are some of those practical implementations that we can actually start looking at into various farming systems as to how to build soil carbon?" Just echoing what Declan was saying, if you have any thoughts or suggestions or questions ahead of that next webinar, feel free to email them through at team@agriprove.io. So, thank you very much for your attention. Looking forward to catching up on our next episode of the webinar. Thank you, Declan, and bye now.

Declan McDonald:

Thank you.