Matthew Warnken:

We'll make a start. Welcome. Welcome everyone to the fourth episode in AgriProve's webinar series on how to grow top soils. I'd like to begin by acknowledging the traditional custodians of land wherever we're viewing the webinar from, and pay my respects to their elders past, present and emerging. Matthew Warnken, I'm managing director of AgriProve, which is a soil carbon project developer that enables landholders to participate in carbon markets and emerging environmental markets with the sole focus of accessing additional revenues.

Matthew Warnken:

And we are hosting this seven part series. Very fortunate to have Declan McDonald here, Principal Soil Scientist with Regen Soils to help unpack this journey on how to improve soil health, and importantly, how to grow soil carbon. Declan, as many of you will know, is a certified professional soil scientist, a wealth of experience spanning over 30 years in private and public roles, and very well placed by these unique insights into growing soil carbon, where are at what we, I guess call the hump episode of this seven part series, right smack bang in the middle. So far, the first three sessions have covered how soils work and how plants grow, organic matter, the cornerstone of soil health and sustainable production. And the last episode was soil biology, millions of years in the making.

Matthew Warnken:

And that was a real fascinating look on biology and really captured the complexity of soil biology with the different classes, microflora, microfauna, mesofauna, macrofauna, and just the function of soil biology, importance of its cycling, organic matter, and other aspects such as soil structure, nutrient supply, pests and disease, pressure, water quality, and obviously, from our perspective, greenhouse gas capture and release. And I thought the last webinar was really great too, just in terms of the conceptual linkages, and everything from Italian Mafia, from the 80s production system and thought of just in time, and yes, I've always thought that while soil biology may be millions of years in the making, it's soundtrack will be well and truly defined by the music from the 80s. So I'm looking forward to some more of those 80s references, Declan.

Matthew Warnken:

This webinar is on mineral management, the role of macro and micro elements. And as always, before we start, just some general housekeeping, we are recording each webinar so they will be available on our website. So very easy to catch up if you do miss a session. We're going to run for around about an hour. Declan will speak for 40 minutes, and we'll have some question time at the end. We're also streaming on YouTube Live. So there is a chat pane on YouTube Live there for questions and comments. And then please also, if you're tuning in via Zoom, use the Q&A for questions and feel free to ask or post any comments throughout the webinar. If you're watching this as a recording session, feel free to also send an email to team at agriprove.io.

Matthew Warnken:

We'd love to pick up any comments or questions, that feedback that you may have. And that we're going to try to get to some of the questions from last webinar at the end of this question period today as well. So without any further ado, Declan, I invite you to start the formal part of this presentation and looking forward to mineral management. Thanks, Declan.

Declan McDonald:

Okay, thank you, Matthew. Hopefully, you've got my opening slide up there on the screen.

Declan McDonald:

Welcome everybody, as Matthew said, we've covered all from on the basics of how soils work and how plants grow. Then we moved to what I think is the most important part, which was soil organic matter. Last week, we talked about soil biology, and this week, we're talking about mineral management. Now, mineral management is, I guess, in simple terms, it's where we're kind of putting our first toe in the water of soil chemistry, because here we're going to be talking about plant nutrition to a large extent. And plant nutrition is very much in the realm of agronomists and agronomists are very good at knowing what fertilizers to use, and usually how much of them to use.

Declan McDonald:

They're very good with species selection like pasture selection and crop advice, and pest and disease control, and all that kind of thing. So I'm not really going to spend much time there. What I really want to talk about is how we want to manage nutrition and how we want to manage the mineral component in a regenerative agriculture context. So as I might have said before, my experiences has told me that our use of these very powerful tools that we have, our fertilizers and our pesticides and herbicides, and everything else, our use of these has been very blunt, we've used them like blunt weapons, and we have not used them in conjunction with soil function, we have not really used them to enhance soil function, we've used them to replace soil function. And we have done so, I think at our cost.

Declan McDonald:

So that's contextualizing the talk today. So just to start with, and this is a reminder of the components of a healthy soil, and you'll see that the organic fraction, 5% is reasonably good in a lot of soils, is comprised mainly of humus, which we talked about in the organic matter section, and organisms, which we talked about last week on roots, which make up a really small proportion. But as we discussed, this small part of the pie here punches so far above its weight in terms of being the primary energy source, so much of what goes on in soil and its nutrient holding capacity, and we talked about that too. So we've got air and we've got water, but the mineral side is really where the soil has come from.

Declan McDonald:

Now, where does soil come from? Well, in very simple terms, soil comes from rocks. And what this photograph here is showing is, that's the mineral component, that's the organic component. So the organic is everything that was living or once living, and that is living or was once living and the mineral component is really things that have come out of the Earth itself and principally out of the rocks. So the minerals are the non-organic component of the soil, and soils are derived from all manner of different geologies, but to pick two of the more common ones, basalt soils they're... soils have different geologies, are characterized by principle properties, such as high calcium and iron oxides in basalt-derived soils, granite soils being high in potassium silicates and the like. Basalts tend to be fine textured soils and granite tend to be coarse textured soils. So these are generalizations, but just so that you understand that the kind of soil we're dealing with is very much a product of the geology that the soil was formed on.

Declan McDonald:

Now, I've got a few very easy slides, which I'm not going to go through but because you'll have a copy of these, it might be a useful reference point for you further on. But this is how we typically think about the principal elements, so these macro elements, nitrogen, phosphorus, potassium, sulfur, they've all got different roles in the plant, and we understand that really quite well, these have been well studied over the years. Similarly, calcium, magnesium, sodium are macro elements as well because there's a lot of them in the soil and certainly calcium and magnesium along with the others are used... there's quite high demand for them in plants for the reasons listed here. Sodium is usually a problem element for reasons that we'll talk about going forward.

Declan McDonald:

And hydrogen is something that's really not mentioned but it's a really a very significant element particularly in acidic soils, where the cation exchange complex is quite dominated by hydrogen. Now, this has good aspects and it has less good aspects, but I'm mentioning it to draw your attention to the fact that it is there and we will be paying attention to it. And then we have the micro elements. Now, these are just as essential as the macro elements, the only difference between macro and micro elements is in the proportions of these elements that the plants need. So plants need a lot of nitrogen and phosphorus, for example, but they need very small quantities of iron, manganese and copper, boron, et cetera.

Declan McDonald:

Some of the other elements that we need to be aware of are molybdenum, silicon, chlorine, cobalt. Cobalt is something that's coming on our radar a little bit more recently as we're understanding the importance of biological functioning because cobalt is essential for B12 synthesis, which we don't get from plants but just about everything that lives in the soil has a demand and a requirement for B12. So if we've got a B12 deficiency in our soil, it's going to impact on the living fraction, on the microbial and larger life forms in the soil. Chlorine is mentioned here because of problems in soil as well in terms of its salt content. But some species for example, brassica have a requirement for a certain level of chloride in their metabolism. Silicon is one that's really coming to the fore in recent years as well, and we're increasingly understanding that this has got really important roles in plant metabolism in terms of facilitating uptake of a whole range of elements, and not to mention its importance in the plant itself.

Declan McDonald:

And silicon has been shown to be particularly important in monocultures in grasses. So there's been a fair bit of work now on sugarcane and silica is recognized as an important ion for sugarcane production. And in fact, the Japanese have been live to this for a lot longer than we have, in terms of its importance in rice production. So all of these are the kind of the building blocks of life and we certainly need to be managing these and understanding how plants access these and how we can facilitate access to these by plants in ways that doesn't involve the expense of us mining these things or manufacturing these things, shipping them halfway across the world and using petrol and diesel to get them onto our farms and spreading them at levels that are probably going to impact on the machinery that already exists in the soil to deliver these elements to the plants. So that's the direction that I'm coming from. Now, when we start looking at plant nutrients, we need to understand soil of testing. So there is not nearly enough soil testing going on, really run across the board.

Declan McDonald:

So some farms are great with soil testing, but the majority are really poor, not to put too fine a point on this, and too often I've been told that fertilizer decisions are made by accountants. And custom and practice, I put this on every year and it seems to work so I'm going to keep doing it. And so often when

I've tested those soils I find that there's a whole lot of one thing and very little of something else and so the production is constrained when we have limiting factors for example, really low nitrogen or really low sulfur or the like. So soil tests have two types of information. One is telling us information about the plant nutrient status, and they'll tell us also about organic matter, organic carbon as well. And the other information in a soil test relates to the condition of the soil, its structure, its bones, if you like.

Declan McDonald:

So this part of the soil test here is usually telling we've got, sorry this is a bit small to read, but you've got nitrogen, phosphorus, potassium, et cetera listed along the side here, and you'll have some numbers telling you what the soil test result is here. And you might have a bar graph saying whether it's high, low or medium. One of the things to understand with really all elements in the soil, not just plant nutrients, but all elements, is that if there's too much of one thing, it means there's too little of another, this was a quote that I heard from Neil Kinsey, who's a quite a famous American agronomist, who has continued the legacy of a famous William Albrecht who was a leading soil scientist in the United States back through the 30s and 40s.

Declan McDonald:

Well, what this simply means is, too much of one element can impact on another. So this is called the Mulder's chart, presumably after Mr. or Mrs. Mulder, whoever that person was, developed up this chart which illustrates the antagonisms, or complementarities and stimulations between different elements. So this takes a little bit of looking at to figure out what the different relationships between different elements are. But I've put a few examples out here, so too much phosphorus, for example, impacts potassium or zinc uptake, too much nitrogen can impact potassium or copper uptake. And too much calcium can impact other cations and can impact boron uptake as well. So it's like there's only so much room in a plant for nutrient elements. And if we have too much of one thing being taken up, because of say, very high level in the soil, it's going to impede the uptake.

Declan McDonald:

So plants are trying to assert an internal balance in the same way that we are. But if that is prevented by their environment and the availability of nutrients, then that's going to be manifested in either poor plant growth or pest and disease pressure. So this is the other half of the soil test that I wanted to draw your attention to. In this example, we've got pH and EC showing here, but here we've got the cation balance. So this word is cation, and it relates to positively charged ion. So when an atom, if you like, forms a compound with another atom, they will shed or gain electrons to allow them to connect to each other, the simplest example is sodium chloride, where sodium has one positive charge, chloride has one negative charge and so they connect in quite a stable lattice structure.

Declan McDonald:

The soil test is also telling us what the cation exchange capacity of the soil is. And this is a measure of its nutrient holding capacity, like we have discussed. But I want to talk about this cation balance for a minute. And the cations are a group of positively charged ions in the soil which include calcium, magnesium, potassium, sodium, hydrogen, and aluminum, are the principle cations. Many of the trace elements are cations too, but they're not around enough of a level to influence what I'm about to talk about, which is sort of structure. Now, one of the reasons I think why so few people soil test is because they're so damn confusing. And there is not a standardization between the way soil test results are presented. And just to confuse you a little bit, if I haven't already, this is an example of the way some soil tests are presented, where we have exchangeable calcium by one particular method.

Declan McDonald:

We have exchangeable calcium by another method. The exchangeable calcium is reported in centimos of positive charges per kilogram, in kilos per hectare, in milligrams per hectare, they're all different numbers, and that really is very confusing. And if you're not confused enough about that, they're also presented in terms of percentages of the cation exchange capacity. Let's stay with this concept for a minute because I think it's probably an easier concept to grasp than some of those other more complicated measures that I was just referring to. So this is showing here that in different types of soil, heavy, medium, light and sandy, there needs to be slightly different proportions of calcium, magnesium, potassium, et cetera.

Declan McDonald:

Probably a slightly better graphic is this one, which shows that calcium should be the dominant cation in a soil followed by magnesium, followed by potassium, followed by hydrogen, followed by sodium, followed by aluminium. Now, the reason, and if I just go back a couple of slides to this confusing one, the reason why these elements are presented in all of these different units is because if I'm interested in calcium or magnesium or potassium, as a plant nutrient, this is the figure I'm going to look at here probably, kilograms per hectare or milligrams per kilogram. This is giving me information.

Declan McDonald:

This is information that I want to look at if I'm concerned about have I got enough calcium, magnesium and potassium to support plant health? When I look at the cations through this lens, I'm understanding that the cations alone amongst all of the nutrient elements in the soil, so this does not apply to potassium, or to, sorry, it does not apply to nitrogen, or phosphorus, or sulfur, these elements don't have a role in soil structure.

Declan McDonald:

The cations are unique in that they also have a role in soil structure as well as plant nutrition. So we need to have them in these proportions because of their contribution to soil structure. So calcium does the most heavy lifting in the soil, we need most of it. Magnesium is next, potassium is next. And so it goes. So by way of illustration, we understand that soil is a mostly aerobic matrix, and it's important to have soil structure for adequate and effective air exchange into and out of the medium. And I use this example as a sponge here to indicate what soil looks like, if you were to look at it under a magnifying glass, it's got all these pores of different sizes. And if you were to look really closely, you'd see there's even tinier pores that you can see with the naked eye. And this allows obviously water to flow into that sponge really quickly. And when you squeeze the sponge, well, it's immediately those spaces bounce back and are immediately replaced by air.

Declan McDonald:

So in the soil, what sustains this pore structure or the principal elements that sustain this pore structure? And this is a skeletonized version of the sponge, if you can imagine, what supports these pore structures and the integrity of the pores is principally calcium, magnesium, and organic matter. Now, of these three, organic matter is by far the most powerful. It is by far carries the greatest weight. Calcium is next in line, and magnesium is next in line. But there's orders of magnitude between each of these in terms of their capacity to protect pore space integrity. And the little example that I think is easy to give us the Sydney Harbour Bridge, so the giant beams that really create the shape of the bridge and do all the heavy lifting, that's the organic matter.

Declan McDonald:

These next largest members here that support the biggest members, but occupy smaller spaces would be the calcium. And the smallest little straps up here would be the magnesium and so it goes. I'm really oversimplifying here, but hopefully you get the intention of all I'm saying. Now, I've shared this slide before, but I'm just making the point again, the reason why it's so important to maintain this structure is because of the performance then of the nutrients that we apply to that soil. So when we put on our nitrogen and we put on our phosphorus, if we have low organic matter, low calcium to magnesium ratio, high sodium, which is really harmful to soil of structure, it doesn't matter how much nutrient we put on, we're going to get sub-optimal performance and we're going to be growing low levels of our potential crop maximum yield.

Declan McDonald:

But if we pay attention to our organic matter, if we pay attention to our calcium and magnesium ratios, we will have good soil structure, we'll have protected pore integrity. And when we put the same amount of nutrient on, we're going to get high production because just like when we squeeze that sponge, we are allowing maximum air exchange and water infiltration into this soil as opposed to this soil over here. And with this soil over here, it's probably waterlogged, it's a bit suffocated, it's a bit suffocated, and it's just not going to grow well irrespective of the nutrient inputs, nutrient use efficiency. So the efficiency of the nutrients that we're applying on this soil here, are vastly inferior to the efficiency of the same nutrients that were applying to this soil here. Now, when you consider that this farmer is spending the same amount of money on nutrients as this farmer over here, this guy is probably losing money, this guy or girl is making money.

Declan McDonald:

So these are some figures which I don't want you to look at, but again, to illustrate a point that came out of work that I did when I was with the Victorian Government, we had a joint project with Monash uni, and we were looking at nutrient use efficiency on farms that were using conventional and compost as inputs and conventional only. And we looked at the nutrient use efficiency of individual elements of nitrogen, phosphorus, potassium, and sulfur. And we did this with quite a sophisticated nutrient budgeting tool that was developed by the Victorian Ag department out of Ellinbank. We rejigged this information here to say, "okay, well, who scored number one and who scored number 12 for the different elements."

Declan McDonald:

And we saw that farm number one here, which happened to be a conventional and compost farm had the best nitrogen use efficiency, the best phosphorus use efficiency, but had only the fifth best potassium use efficiency, the third best sulfur use efficiency. This farm here, farm number two is also conventional and compost, but they were way down the line in terms of their nitrogen use efficiency, third from the bottom, second from the bottom with phosphorus use sufficiency, et cetera. So when I just re-order these again, and say, "Who got the best overall ranking?" Actually, this was interesting to see here, if I go back to the first one, you'll see that farm number five here had very high nitrogen use efficiency, very high phosphorus use efficiency.

Declan McDonald:

So basically, when we came through and did the ranking, we saw farm number five actually nutrient use efficiency across the four elements, this guy came out on top. Interesting that the top three were all using compost, the next two, obviously very good conventional growers. We had one compost grower down in the bottom, but the bottom five, four of them were occupied by the conventional growers. So what does this mean now then for how we feed plants? Know that the fertilizers make plants grow, but there is no such thing as a free lunch. And this author here wrote about the myth of nitrogen fertilization. And basically what he and his team lifted the lid on at the time was the emerging awareness that in spite of, and I mentioned this last week too, in spite of high application rates of nitrogen fertilizer and large return of plant residue to the soil, the amount of carbon that was sequestered in the soil was way below what would have been predicted by the belief that said, you sequester carbon by growing bigger plants and returning plant matter to the soil.

Declan McDonald:

The phosphorus buffering index is a measure of soils capacity to grab phosphorus when it is applied and lock it up and make it unavailable to plants. And this process can happen really quite quickly in over the space of just a few weeks following application. And it doesn't matter, phosphorus levels in the soil can be quite high, but plants just aren't able to gain at them if we have impacted on those soil functional properties, such as mycorrhizal fungi and phosphorus solubilizing bacteria whose job it is, is to unlock phosphorus from these soils and make them available to plants. Khan, the same author in 2013 talked about the potassium paradox in this paper which looked at the lack of response particularly to the application of potassium chloride, and whilst he hasn't furthered a sound reason for the poor performance of potassium chloride, and this was over about 2,000 studies, the presence of 51% chloride in this compound and it's very high salt content appears to have a negative impact on soil biological function.

Declan McDonald:

And then we have things like the leachability of anion. So a constant battle in our soils is if we apply nitrates to our soils, keeping them there available for plants to uptake and nitrites are part of the nitrogen cycling story and they are also very leachable, but so also are sulfates, the ortho phosphate ions, which are the form in which phosphorus is taken up by plants and borate, one of the forms that boron is taken up by plants as well. So anions, the negatively charged elements are generally weakly held in soil unless there's high organic matter because organic matter has got anion exchange capacity, whereas most of our soils in Australia don't have much anion exchange capacity. So this has led to what is sometimes unkindly referred to as the more on approach. And I've spelled it here, more on, as in, if you have a problem you put more on, other people would spell differently.

Declan McDonald:

And this was something that came to my attention just recently, this was from the University of Colorado's newsletter, saying that one third of the fertilizer applied to grow corn in the US each year simply compensates for the ongoing loss of soil fertility, and what that means is the loss of organic carbon, the loss of topsoil, leading to massive additional costs for US farmers, where the natural fertility of the soil has to be replaced out of a bag at considerable expense. So what happens when we fertilize? Well, as we've talked about before, we make the workers redundant, the mycorrhizal fungi, the bacteria that live in association with the plant in mutual associations, don't get fed and die off in effect. And in addition, we lose the social connection between plants and soil partners, and you'll recall we talked about that last week also in the context of the Dutch grassland study, that showed the important role of fungi in connecting elements of the soil biological and plant communities together.

Declan McDonald:

And we make plants lazy, and the example there is how the nif gene is turned off in legumes, which is the gene responsible for nodulation. So there's no home for the rhizobia because the plants don't need to support the rhizobia because they're living in a sea of nitrogen applied from on top. But force feeding in this way does make plants grow, and so we have become a bit addicted to this as a mechanism to sustain production. Cultivation also contemporarily improved growing conditions at the depth of cultivation, particularly if compaction has previously been impeding production. But all of these things mean, the redundancy of the workers mean that the soil is not being maintained, particularly it's not being maintained a depth and as a result of structure and function declines.

Declan McDonald:

But we still have to make a profit, how do we make this work? We find ourselves now between a rock and a hard place. Now for me, the way I look at regenerative agriculture and regenerative soil management is about saying we kind of have to have our cake and eat it too. And I say that because growers can't turn around overnight and say to the supermarkets, you're not paying me enough for my goods, and they're not able to dictate to the market what the price should be. So we're still under a really significant cost constraints in terms of how we grow our food. But what we haven't really factored into our growing equation is, how do we grow our food and improve soil at the same time? So the twin aims for me, for regenerative agriculture, which really involves leaving the farm in better condition, which is a fairly common aspiration amongst farmers, is growing profitable crops, animals, fiber, et cetera, and as I said, improving soil quality at the same time.

Declan McDonald:

So the first decisions really relate to how little fertilizer can we apply? There's a famous American farmer, agronomist called Gary Zimmer, and he talks about earning the right to use nitrogen. So he makes the point that farmers that don't know how to make grass grow will buy a bag of urea, throw it out there and will make grass grow, but they don't really know how that has happened and they probably don't know how to do it without the urea. So what Gary Zimmer says is, you've got to understand soil, you've got to understand how soil grows, how soil works, and then if it's appropriate to use fertilizer, if it's appropriate to use nitrogen, using it appropriately, which means using it at the lowest level that you can get away with, and at the same time, making sure that that level does not negatively impact soil function.

Declan McDonald:

Now, in very simple terms, the higher the level of organic matter, the less we will need to apply, and this kind of gets to Zimmer's point that the higher the soil function, the more nutrients are being cycled naturally in that soil, the less augmentation is going to be needed, but we do have productivity targets, we do have bills to pay, we do need to hit our targets. We also need to ask though, how do we stimulate both soil biology? Particularly early in the crop and how do we maintain high soil biological populations? We don't want to suppress them by throwing on a heap of fertilizer that's going to put them out of work. So, the second decision then needs to relate to the formulation used, experience has shown that some formulations of fertilizers are positively deleterious, other forms are health giving.

Declan McDonald:

So we need to be judicious in our selection of the formulations we use. So, for example, nitrate and ammonium are good forms and appropriate forms of nitrogen, but ammonium has a lower energy demand on the plant, whereas nitrate needs to be converted inside the plant, ammonium can be used as a building block straightaway. So ammonium nitrogen has a higher efficiency value when uptaken by plants. In the case of potassium, should we be using chloride or sulfate? Well, chloride has been shown to be deleterious whereas sulfate has been shown to be supporting of healthy soil function. Foliar feeding is something that's allowing us to be much more targeted and nuanced in our fertilizer application.

Declan McDonald:

Placement and timing are always important irrespective of what we use, and also fertilizer buffering, and this is either buffering the effect of the fertilizer on soil microbial communities, or aiding its uptake, and particularly fulvic acid here, if used in conjunction with foliar feeding can greatly increase the efficiency of plant uptake, thereby, meaning you can use less. We've got to look at biological fixation of nitrogen in particular legumes and rhizobia, azotobacter, clostridium are free living nitrogen fixing sources in soil that is not growing in conjunction with legumes. And cover cropping and intercropping, this is very much about stimulating diversity in the soil community and stimulating that nutrient cycling and nutrient capture. So if we have a much higher biological population in the soil, we're going to have more of these guys in the soil, we're going to have more nitrogen capture and cycling.

Declan McDonald:

And we very much need to use organic matter to drive these fertility cycles. Now, you might be interested too and surprised to realize that the vast majority of nitrogen in the soil is in organic forms, so in other words, it's tied up in the soil organic matter pool. The nitrogen fertilizer that we apply is a super available form of fertilizer usually, and so the plants suddenly become awash, preferentially if it's easier for the plant to access it rather than negotiating with its partners in the soil. But recently, research has shown that measurements of nitrogen availability at the scale of roots rather than in the bulk soil, this was in a sugarcane plantation, showed the plants were not able to fully capitalize the very high nitrogen concentration in the soil applied by fertilizers. So we have a feast and a famine situation where suddenly, there's too much for the plant to be able to take up. This is where leaching occurs and this is where wastage occurs, but the plant is not able to utilize, so we have low nitrogen use efficiency in effect.

Declan McDonald:

But between fertilizing events, when this kind of ready soluble pool ran out, and the plants still needed nitrogen, it turned to the organic pool. And it was able to access that nitrogen more efficiently, mainly in the form of organic nitrogen in the form of amino acids. So I showed you this slide last week, but again, just drawing attention to the fact that the nitrogen is here in the soil organic matter pool. And we have this relationship, as we talked about last week also, between the different elements, and you'll see that the relationship between carbon and nitrogen in soil organic matter, in stable humus is about 12:1. And most soils that we test, we find, unless they're fairly unhealthy, will have a natural ratio of 12:1, carbon to nitrogen, and this is where we want to be. But we want to have fresh carbon and fresh nitrogen coming into the system so that this nitrogen and this carbon cycles.

Declan McDonald:

So in terms of understanding how quickly we can access the nutrients out of organic matter, I developed a compost calculator a few years ago that looked at these are the nutrients in the compost, this is the soil nutrient status here, and this is our organic matter status here. So when we put this through the black box of our calculator, we say, Okay, well, this farmer is applying compost of five tons to the hectare, 20% moisture and four tons dry going onto the paddock. In the compost per ton of compost or milligrams per kilogram, this is the total nutrients supplied based on the four dry tons application rate. This is the increase in soil that you get from those additional nutrients. That's the existing soil concentration, the new soil concentration, and then it allows us to work out what the supplementary fertilizer requirement is.

Declan McDonald:

Now, built into this model here is the fact that organic matter of any form really gives up its nutrients very slowly. And that's because as soon as some nitrogen starts being released from compost or from a cow pat or whatever, because nitrogen is this really volatile element that we've talked about before that escapes very readily, nature has designed mechanisms to grab it really quickly, and that's it's grabbed by the microbes in the soil, they'll always get it before the plant will. And after they get it, the plant can have some, but they'll get it first. So what that means is maybe only 10% of the nitrogen will become available to plants in year one, four or 5% in year two 3% in year three, so we have this diminishing release. But if it's going on every year, in year two, we have year two of year one's application plus year one's application. In year three, we have a compounding year one, year two, year three residual, and on it goes and I'll expand on that idea before I get to the end.

Declan McDonald:

So when we're feeding microbes and plants at the same time, we want to feed them with fertilizers that have a health-giving form or that have a low energy requirement for plants to uptake such as nitrogen in the ammonium form and sulfur, which has a whole bunch of beneficial metabolic functions for both plants and soil microbes, same with potassium sulfate. When we look at liquid nutrition, this is a really good way to manage some of our trace element deficiencies, and certainly trace elements really do need to be paid attention to although some people are making a bit of a religion about trace elements, they need as much attention as the macro elements, we certainly need to make sure that they're in sufficient quantities, but applying them in a foliar application is a very efficient way of making sure that the plants have enough, particularly if we're talking broadacre.

Declan McDonald:

And these are just some example application rates to show that it can be a very cost effective way of going about it. At the same time, we try and bounce this up with compounds that will help to stimulate microbial function at the same time to both process these elements or to cope with the dump of even though this is a preferred form, if there's a very high concentration of this, it's going to be locally toxic at the micro scale to soil microorganisms, and they will need help recovering. So we've talked about the role of humic acid and fulvic acids as a carbon source with foliars and things like molasses, compost extracts, and seaweeds, they all have their places.

Declan McDonald:

Well, these are not all directly interchangeable. So for example, molasses is a really good bacterial stimulant, but it doesn't do much for fungi. In contrast, fish is are good fungal food, but not so good for bacteria. And seaweed is particularly good for raising plant betaines which help with plant stress responses. So for example, some work I did in Tasmania years ago, we showed that betaine increases in response to seaweed applications, gave us about an extra two degrees of frost tolerance. This little graph here is just highlighting that point of the relationship between soil microorganisms and plants and the materials that are exchanged between the three to support nutrition.

Matthew Warnken:

It's Matthew, we have just a bit under 15 minutes to go.

Declan McDonald:

Okay. I'll wrap it up, Matthew. Just very quickly, I've said slightly provocatively that there's nothing wrong with urea. It's ideal for foliar applications, it's used quite efficiently in the plant, but the way that we apply it is what does damage to the soil in broadcasting as hundreds of kilos over a season. So we want to favor organic nitrogen for all of these reasons, organic and inorganic forms coexist in the soil because organic nitrogen needs to be converted to inorganic forms to be taken up by the plant, but the plant can also take up amino acids, amino acids also contain carbon and plants require both nitrogen and carbon for biomass acquisition, and carbon gained from amino acids taken up by the roots and foliar urea, for that matter, represent bonus carbon that the plant didn't have to manufacture, thereby improving nitrogen assimilation efficiency over inorganic N.

Declan McDonald:

And a few just example here, this is a farmer in Gippsland who has been using compost and fertilizers on a high organic matter soil, a range of trial plots and a range of different treatments. This trial was overseen by Gippsland ground spread, and there's been substantial improvements demonstrated here, my feeling in reviewing this trial data was he could really back off a lot more on the amount of fertilizer and nitrogen in particular that he's using, because of the demonstrated benefit that compost is contributing to a soil. And the final and slightly blinding slide that I wanted to show you is what this is showing is that the mineralization of nitrogen in year one is 10%, year two 4%, subsequent year 3%. But you can see if the same amount of compost or manures are applied year on year, we have this compounding effect where it might take 20 or 30 years for one application to be fully mineralized in the soil.

Declan McDonald:

So we have this compounding effect where it's going up and up and up. This is why it takes soil quite a while to develop, to reestablish natural fertility. It's why organic growers say it takes seven years for a soil to start firing, others say it takes 10 years for soil to start firing because we need to get this happening here, we need to get the natural delivery and accumulation of nutrients up in the organic fraction of the soil so that nutrient cycling out of this great vault of material here is suddenly up to or gradually up to meeting the demands of crop production. Okay. Thank you, Matthew, back to you.

Matthew Warnken:

Great, thank you very much for that, Declan. As always traversing such a wide range of materials. I think that just that concepts around mineral management and maybe the first time the water for soil chemistry and nutrition, I think what really came through was the challenges and the tongue twisters, as it felt like we were back in year seven science canvassing much of the periodic table of elements, and certainly my favorite, which is molybdenum, but look, just great to cover off that geology is the foundation of soil and soil mineral, not only soil's nutrition, but also soil structure. And again highlighting for me just the importance of air in terms of that soil structure, the challenges facing in terms of well, how do we actually measure soil test, not only getting soil tests, and how do we decipher those results? And the balancing aspect and again, some great visual concepts with the Mulder's chart, the ball string in terms of those potentially antagonistic impacts of nutrients, the sponge average in the rainbow nitrogen graph.

Matthew Warnken:

And probably for me, a key takeaway was just that fact, I think it was a third of fertilizer application to US corn production are just going to make up for that loss in soil function. And then maybe thinking around just that use of urea or applying nitrogen, you said like putting more on, I was actually questioning, well, how little of fertilizer can we actually apply? So there's a lot there to cover. Maybe just some questions that are coming through, but just in terms of that importance of balancing nutrients in the soil, how easy is it to over balance? Especially say like with adding micronutrients or adding nutrients to soil, and then what's the impacts in terms of some of that overbalancing aspects?

Declan McDonald:

Yeah, look in agriculture, it's easy to do in any system. I do work for a number botanic gardens in Victoria. And one of the things that we find there is surprisingly, the soil nutrient levels are really quite high. And they say, "Oh, we don't fertilize very much." And I say, "Yes, but you take nothing away." So they bring in mulch, if they prune a plant, they'll mulch it, and they'll keep it on site. So there's no nutrient removal happening there. So over a long periods of time, they become nutrient sinks. So in farms, at least, usually we're exporting nutrients so there's a requirement to replace those nutrients. But if there's no soil testing and there's no thinking about the strategic use of fertilizers, and if I'm just applying two in one every year, I'm going to have lots of the two and I'm not going to have very much of the many.

Declan McDonald:

And I've seen this time and time again where, and I haven't shown but most people will be familiar with the concept of Liebig's barrel, and Liebig would say... the so called grandfather of chemical agriculture, and he identified that you can have a full bucket of nutrients, but if you're really low on one essential element, so for example, phosphorus, the whole production system is going to be compromised. So yes, it's easy to overdo it. We can overdo it to the point of toxicity with some elements. Some elements are naturally elevated in our soil, so for example, out in the Wimmera, they have issues with boron, generally below about 30 centimeters in the soil at toxic levels and roots are getting pruned off there. So it can happen naturally. But generally, we can avoid those kinds of problems with soil testing and with strategic use of fertilizers. Your music, Matthew.

Matthew Warnken:

Thanks. Just maybe picking up on that soil testing, one of the things you were talking about was phosphorus buffering, how would you go about testing for that buffering impact or other indicators that phosphorus might not be available for plants and again, what might be some of the flow on impacts on plants and soil functions for that matter?

Declan McDonald:

Yeah. When we test phosphorus in the soil, and there's a number of different tests we can do for phosphorus, but the Colwell test has a component to the test which determines the risk associated with phosphorus lockup. If we are on say, a sandy soil in a coastal location that's got a low clay component, we're not going to have a phosphorus buffering problem. The phosphorus buffering indexes on those soils are usually very low. And so the amount of phosphorus that you put on is the amount of phosphorus that theoretically becomes available to the plant.

Declan McDonald:

If however, you're on say a potato soil, a red ferrosol, they have extremely high phosphorus buffering indices usually, where the phosphorus gets locked up and it doesn't matter what the plant does, it struggle to access those supplies. And in fact, years ago, there was a farm being sold down in the Heytesbury district in southwestern Victoria, and we had done some nutrient mapping on his farm, and half his farm was in the red zone because he had so much phosphorus locked up in those soils. And he included it in the real estate package saying to the new owner, "Look how much phosphorus you're getting with the sale of my farm." Unfortunately, it was largely unavailable.

Matthew Warnken:

Declan, maybe just again, concepts around threshold, so a question around what might be a threshold for, say, organic matter in sandy soil. So if you're able to get to a certain level of organic matter, then the soil just sort of exponentially or orders of magnitude improves, whether there's a threshold there in sense or then is there a similar threshold cited by these soils?

Declan McDonald:

Yes, soils sequester carbon to the extent that they're able to protect the carbon from microbial decay. So clay soils have got, if you like, good mechanisms to be able to protect carbon, and in very simple terms, carbon is protected by clay skins, if you like. And that's it forms a bit of a shield against microbial decay. Now, when all of those, and this is really oversimplifying things, but if all of those clay skins, if you like, are used up in a soil and the soil is not able to protect that carbon anymore, it's going to be degraded by soil microbes much more easily. Now, in a sandy soil, the sandy soils don't have those same protection mechanisms because they're low in clay.

Declan McDonald:

So organic matter that's applied to a sandy soil generally is going to get used up quite quickly, we'll see a burst of biological activity in those soils that won't be sustained once the organic matter runs down. What it means is that every soil has got an upper threshold of really how much organic matter it's able to hold. Which is why in sandy soils, if you have an organic matter content of 3%, you're probably pretty happy, if you have got a clay loam soil, or a loam soil, and you've got an organic matter of 8%, you're probably pretty happy.

Matthew Warnken:

Declan, we're running right up against in terms of time for this webinar session. But I did want to just maybe get your thoughts on a couple of things that you mentioned. So then the importance of bacteria, I think, you talked about rhizobium bacteria, but then there's another two that came up, forgive the pronunciation, but the azotobacter and clostridium, how do those bacteria work in terms of cell function? And how do you increase the populations there?

Declan McDonald:

That's quite a difficult question, Matthew, and I'm not sure I fully know the answer to it. The conventional wisdom tells us that, and this was some work done by researchers in South Australia saying that we have relatively high populations of free living nitrogen-fixing bacteria in high carbon soils. So where we have a soil that's very low in nitrogen, that might have a carbon to nitrogen ratio above 12 might be 14, 15, something like that. So nature has this mechanism where it brings in free living nitrogen fixing bacteria to try and correct that. The same research says that in a soil that's got an appropriate carbon to nitrogen ratio or a low carbon to nitrogen ratio, that you don't get so many of these free living nitrogen fixing bacteria.

Declan McDonald:

That has been confounded by some farmers that I've worked with, and particularly the largest organic farmer in Tasmania, who was growing big broccoli crops with no nitrogen inputs. And when I discussed it with my colleagues, there's all kinds of speculation about what was going on, but the only way I could really answer that question is that there was nitrogen coming into the system from somewhere. So I think the jury is still out on that, I'm not sure that we fully understand the ebb and flow of these populations, but I suspect that they are more significant than we currently give them credit for.

Matthew Warnken:

Great. Thanks, Declan. And finally, just maybe one final observation, you talked about time horizons to get soils up firing in terms of the length of time, do you have any thoughts as to well, how quickly focusing on improving soil function, is there a way to fast track, maybe that's a better way to put it, fast track the firing up soil function?

Declan McDonald:

Yeah, I think the fastest way to do it is really to do what I've been talking about today, which is to look at your fertilizer formulations and saying, "Okay, where can I pull back?" Soil test, know what you have enough of, know what you need, think about the formulations that you can best provide those nutrients in, and then what kind of supplementation that you can make in terms of organic matter, and that might be buying manures or composting, or it might be say, changing your cropping or your grazing habits to sequester more carbon in the system. If we work on those two parallel streams, that's the fastest way to turn things around.

Matthew Warnken:

Great. Well, as I said, we find a lot to ponder. You've been watching the webinar series, How To Grow Top Soils – The Science of Soil Carbon, this was episode four, mineral management, the role of macro and micro elements. Thanks to the team at AgriProve. Thanks to Mel for putting the webinar together. Very special thanks again to Declan McDonald from Regen Soils. We hope you're enjoying this series. Next week's topic is on managing fertility to build soil carbon. So a nice segue from our last point of discussion that hopefully we can pick up on the next episode. Please send through any feedback or comments to us at team at agriprove.io. Thanks again for your time and I look forward to catching up with you about next session. Bye now.

Declan McDonald:

Thanks all.