A road less travelled

Regen Pioneers

Renowned independent consultant Joel Williams of Canada-based Integrated Soils, put forward his perspective on how to make the transition into agroecology at Hutchinsons' inaugural Agroecology conference, which took place in November last year. *CPM* was there.

By Lucy de la Pasture

With interest in agroecology sharpening, departing from the conventional view is often tricky — with no route through the transition exactly the same. So where do you start?

Joel Williams of Integrated Soils suggests taking a stepwise approach. "Taking steps into the unknown can feel very risky. There's no set roadmap per se, it's nuanced," he says.

"There are many ways to approach the transition and one of those is called efficiency, substitution and redesign (ESR). This is a way to plan a stepwise approach and to conceptualise the transition from your current production system towards something more sustainable," says Joel.

He highlights that first and foremost, a change in thinking is required. "Conventional agriculture is very much built around the discipline of agronomy, which is often very input dependent. We use a lot of science and technology to manage a system we consider is under our control. But it isn't really how natural ecosystems work," he says.

"If we want to have this discussion about agroecology, we need some element of biomimicry. We're looking at natural processes and trying to harness or mimic them, bringing them into the design of our agricultural systems. We have an immediate kind of juxtaposition — the classic agronomy system under control versus working with natural cycles and systems."

But Joel points out that farmers are already good at working with some natural cycles, such as the weather, so the change in thinking required may not be as alien as it seems.

The first step in the ESR system is efficiency, which means optimising the current farming model, he explains. "Let us be as efficient as we can be, use the least amount of fertiliser, plant protection products and diesel as possible. We're still using all of those inputs and we're still managing a conventional system, but it's now a low input, high efficiency system where we're using very small amounts of highly efficient inputs."

Once this has been achieved, substitution becomes possible, says Joel.

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"It becomes easier to drop inputs because you're using a small amount. It's possible to substitute into alternative practices or alternative inputs — these could be biological inputs or softer inputs, depending on the context.

"And ultimately this makes way for the final stage of the redesign. And redesign is the core of agroecology. It's about redesigning the production system to decouple from input dependency so we make agriculture and food production compatible with nature. It's about nature-friendly farming and biodiversity-based agriculture. It's using ecology, ecological principles and biodiversity as assets to then have a productive system to produce food."

Joel emphasises that even though the efficiency and the substitution phases are really important first steps in making a transition, it's important not to get trapped in these two stages. "We have to be taking the steps ultimately to redesign," he says.

And that's because the potential to

make deep impacts in the first two phases are limited, explains Joel. "In redesign, we're mimicking nature and natural ecosystems work in virtuous circles — they're multifunctional and provide other ecosystem services.

"Farming systems typically are not so good at those things. But of course, they are very good at being productive. For natural ecosystems, it's the reverse — they're good at providing some of those ecosystem services and other benefits, but they're not typically as productive. We have to strike a balance somewhere in the middle, and that's really the future of farming."

Joel considers different farming systems — organic, conventional and regenerative — and says it really doesn't matter which type of farmer you consider yourself. "It's just a label at the end of the day. All of those production systems would benefit from more ecology — from bringing in more ecological design and bringing in more diversity. It would benefit an organic system, conventional system or regenerative system, it really doesn't matter.

"Everybody can design more biodiversity into their farming system, irrespective of where you're starting from. Mixed farming systems are a good example of that, integrating crops and livestock is exactly what happens in a natural ecosystem. We don't really see plants existing in isolation."

Efficiency, substitution and redesign in practice

Efficiency – *Reducing the amount of nitrogen applied or increasing uptake by plants*

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Joel goes on to illustrate how ESR can work in practice, using nitrogen as an example. "There are two ways to think about efficiency. One is simply the amount that you use — we want to try to use less nitrogen and/or minimise the losses. But that's just one piece of the puzzle, the other thing to consider is the form of nitrogen and how efficient it is."

Foliar applied nitrogen is one way of improving efficiency over soil applied forms, he says. "There is no leaching from soil and less volatilisation off the leaf. Once in the plant, the N is stable so straight away foliar offers an opportunity.

"But we know it's a lot more nuanced than that and there are many factors to consider, such as formulation — can we supply supporting nutrients to make the N more efficient? Then there's the form of the N itself, is it stabilised or inhibited? What about the application — the pH of the spray, nozzle selection and so on?"

Examining these in a bit more detail, Joel highlights that it's environmental factors that drive the uptake of foliar nitrogen. "You want to be targeting sprays in early morning or late afternoon. High humidity is absolutely essential as it's key to getting nutrients to pass through the leaf into the plant. If we don't have good humidity, and I'm talking really anything from 70% upwards, then the nitrogen is more prone to just sit on the leaf. And the longer it sits on the leaf, it can potentially be washed off or volatilise.

"While stabilisers or inhibitors can help keep nitrogen in more stable forms, other strategies — like applying a carbon source with nitrogen, such as humic and fulvic acid or molasses — can also achieve this. What that carbon source does is to act like a sponge — it binds to and wraps up the nitrogen and helps to stabilise it. And as it becomes a bigger molecule, it's less leachable."

Moving onto to discuss form, Joel highlights that an important function of nitrogen in the plant is to build proteins. So how does form affect this?

"If we use ammonium nitrate or urea, for example, all of these forms of nitrogen have to be converted in the plant via ammonium enroute to amino acids. Some forms of nitrogen are more efficient at this than others.

"When ammonium comes into the plant, it's a single little step to change from ammonium to glutamine — this is one of the very first amino acids that the plant will produce, which then can get turned into all sorts of other amino acids and protein.

Moving to an agroecological approach is about redesigning the production system to decouple from input dependency so agriculture and food production is compatible with nature, says Joel Williams.

"Conversely, when nitrate comes into the plant, it first has to be reduced to nitrite. Then the plant turns that nitrite into ammonium before it can utilise it as glutamine. So you can see here we have a multi-step process."

And what's the significance of this? "One of pathways is long, the other is short. Each step of the chain is a metabolic or energetic cost to the plant and the more steps there are means there's a greater drain of energy for the plant.

"So, straightaway you can see that nitrate is not such an efficient form because it's very metabolically expensive for the plant to turn it into organic nitrogen, into those amino acids, compared with ammonium, for example."

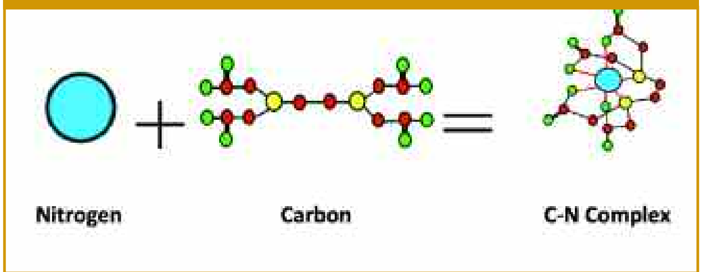
Joel says there's also a cost to the plant in terms of nutrient demand, which is different depending on the form of N applied. "For example, manganese and magnesium are both essential to help with ammonium conversion. With nitrate, there's a greater nutrient drawdown to go through the pathway to ammonium — it requires molybdenum, sulphur and iron to catalyse the initial steps as well as magnesium and manganese for the last step," he explains.

"So when we talk about managing nitrogen, we're not just talking about managing nitrogen. You also have to be thinking about all of these other essential nutrients as well."

Joel asks whether it's possible to bypass these energetically expensive pathways and instead give the plants organic forms — peptides, amino acids ▸

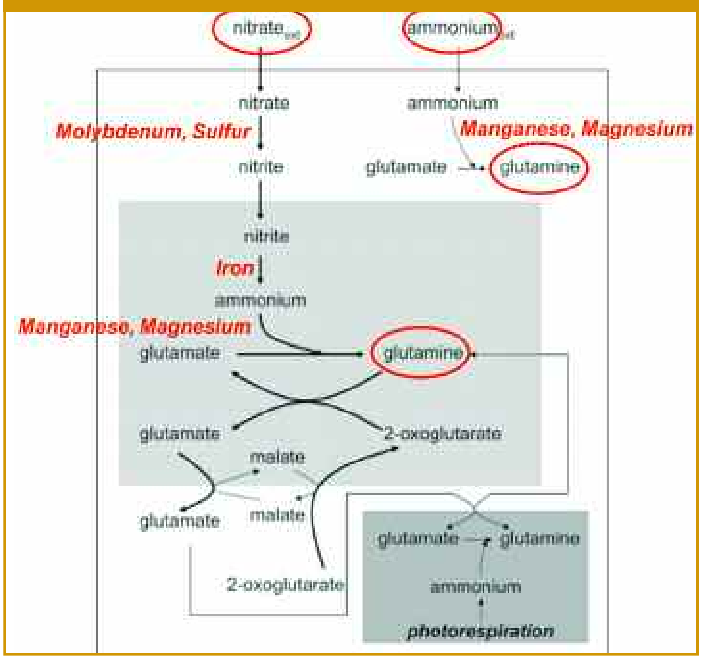
Creating a balanced agroecosystem

Stabilised N



Applying a carbon source with nitrogen, such as humic and fulvic acid or molasses, stabilises it.

Ammonia versus nitrate metabolism



▸ or proteins — in a process known as metabolic shortcutting.

"Organic forms of nitrogen are preferable because they save the plant's energy which can be used elsewhere, such as in growth processes.

Examples of organic forms of nitrogen which can be fed in liquid form are fish hydrolysate, amino acid-based products, composts, biosolids — there's lots of these types of things out there. And this is an emerging piece of rethinking plant nutrition that's happening at the moment."

The classic, traditional views have been really heavily focused on inorganic N forms, adds Joel, but recent research is revealing a different story. "We now know that the plant can take up more complex organic forms — amino acids can be absorbed directly through the roots and bigger proteins can be absorbed directly through the roots as well.

"And even beyond that, plants can absorb bacteria — whole microorganisms — which they can also use for nutrition. It's a rethinking of the whole field of plant nutrition, where we were previously heavily focused on simple inorganic ions."

So when the efficiency part of the puzzle has been addressed, it's time to take a next step into substitution, says Joel.

Substitution

An example of substitution would be to use nitrogen-fixing bacterial products.

Joel stresses that within the ESR framework, the substitution phase is often considered a vulnerable zone. One of two things can happen, you can either get stuck in efficiency and substitution or you can break through into the redesign phase.

"Nitrogen gives a great example. Because when we talk about substituting N inputs with nitrogen-fixing bacteria, biofertilisers and microbials have some big potential — and also some big inherent problems, such as how do you know what you're applying? Is it still alive? Are there pathogens in there?

"If you buy a nitrogen-fixing bacteria, it may or may not work for you and because of your experience with it, you may not progress and transition into redesign. Instead, you may feel 'it didn't really work for me, so I'm going to go back to using foliar, artificial nitrogen'.

Joel acknowledges that biofertilisers have somewhat of a reputation, they can be difficult to use and can be inconsistent at times. "And that is the problem. I will also say that it's a problem that we can overcome once we have filled in some of the knowledge gaps in soil microbiology.

"And ultimately, we're interested in turning nitrogen gas — there's an abundance of that in the air — into the plant available form that is ammonia. But again, it's really important to be holistic because other nutrients are required for the installation of bacteria to fix nitrogen from the air and deliver it to the plant. The bacteria themselves need molybdenum, plenty of iron, nickel and phosphorus on top of the plant's own requirements. And if there is a limitation to any one of these, the potential for nitrogen fixation will be held back. So again, we need to manage all of the systems that are the pieces of the puzzle," believes Joel.

"It's not just about buying and applying a product, doing that you're setting yourself up for potential failure. You have to put the product within a system that's designed for it to work."

Taking the example of nitrogen-fixation further leads into redesign.

Redesign

Redesign an element that brings the diversity back into the system and introduces natural processes, such as nitrogen fixation.

"Legumes with rhizobia can fix nitrogen within these nodules but we also have associative fixing bacteria. These are the bacteria that can associate with any plant whatsoever, they can simply live on the roots and around the root system, feeding off root exudates and fixing nitrogen for any plant.

"We also have free-living nitrogen fixing bacteria, these bacteria don't even need to be on a plant and can still be fixing nitrogen. While there are potential knowledge gaps, there's also lots of potential to harness some of these other nitrogen-fixing bacteria.

"When considering redesign, bringing the conversation back to legumes provides a good example. Legumes are the kings of nitrogen fixation — they can do it the most and the best. So, I think wherever we can redesign these relationships into the production system, the better."

Joel refers to the benefits of diversity within cropping systems. "We want to transition from monocultural, uniform, simplifying landscapes into diversity. That can be done in a whole host of different ways; from cash crops, wider rotations, cover crops, companion and intercropping, biodiversity strips, and agroforestry.

"All of these are great ways to diversify the farming system and therefore diversify the landscape and we could be using legumes as part of that process — bringing in some free nitrogen into the redesign and building better ecological infrastructure to support wider landscape processes."

Joel comes back to his point about getting stuck in the efficiency and substitution part of the process. "A highly efficient farm that has mainly substituted its inputs, and instead is using biologicals, is still a very monocultural, simplified landscape. But one of the other negatives of being stuck at this point is that you're also still stuck in input dependency, you're still buying something even if you're buying biological.

"The thing about redesign is you are decoupling from input dependency, and that's why bringing legumes into the system can be very advantageous. But there's a whole selection of 'plugins' that you could potentially use to move from uniformity to diversity," adds Joel.

"If we use legumes, we can bring nitrogen into the system, but we also introduce multifunctionality. We get so many other benefits from cover crops; from soil protection to soil health, building soil organic matter, improved water supply and infiltration, minimising erosion and all of those kinds of things. There are benefits to the agronomy from unlocking nutrient cycling, nutrients that can improve soil fertility and reduce dependency on fertilisers."

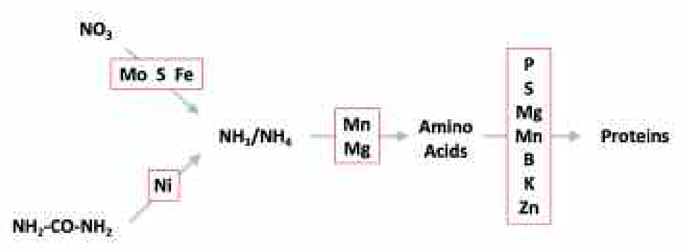
How then can legumes really help us reduce our nitrogen dependency? "It's not just about growing legumes as cover crops to then terminate them, so they die and decay in order to release all of that nitrogen. We can utilize legumes to share nitrogen in real time in the current season — from the legume to non-legume companion — through things like companion cropping or through intercropping.

"When legumes are alive and growing, they're photosynthesising and releasing root exudates. When we talk about root exudates, we're not just talking about sugars, there's a whole host of different root exudates that plants release, some of which are amino acids, peptides, proteins, those organic forms of N we talked about. These get taken up by the plant, but they also get excreted by the plant as root exudates.

"So when we have a legume root system and a non-legume root system growing side-by-side and intermingling, that legume is releasing amino acids as root exudates and its non-legume companion can scavenge those, absorb them and take them up. So we can get direct sharing of organic forms, of amino acids predominantly, but again some proteins may also be taken up," explains Joel.

"And if the two plants are also both mycorrhizal associated, so connected through common mycorrhizal networks, amino acids from the legume will pass through the mycorrhizal hyphae and be delivered directly into the non-legume. So, we do have these two other pathways of real time currency and the sharing of nitrogen."

Nutrient requirements in N metabolism



There's a cost to the plant in terms of nutrient demand, which is different depending on the form of N applied.

The invention of the light bulb was a revolutionary change whereas the low energy light bulb was an incremental change.

There is still nuance to the system, some varieties of legume are better at doing this than others, he says. "For example, small leaf clovers are better at sharing nitrogen as bigger leaf clovers have a higher nitrogen demand, so they hold more nitrogen back.

"We think about plants as so competitive against each other, competing for moisture, competing for nutrients, but we're beginning to see examples where plants actually are very collaborative, and they work with each other and support each other," he says.

Joel's closing remarks provide further food for thought. "If we think about this process of transition and making changes to our farming system, there's a lot of raging debate about how we go about this. Do we take small steps and make positive incremental change? But many of you feel that this is not enough. Some say that we don't need evolution, we need a revolution that brings transformative changes.

"But a really good example of how to think about this process is to look at Edison. He didn't invent the light bulb through incremental change of the candle. He thought out of the box and made transformative change.

"Now, even though he did that, we've gone through incremental change to a modern LED light, tweaking the efficiency of the light bulb without ever getting rid of it. So it's not necessarily that incremental change is bad, but let's not get stuck in incremental thinking. Out of the box thinking can sometimes be very transformative or revolutionary, but change can also be very different stages." ■