Evie Croxford
Okay, so I've just had a thumbs up from the rest of our team. So welcome to everyone who's streaming to watch our second keynote speaker of the Bio-Diverse Festival 2020.

I'm here with Professor Duncan Cameron, who I will introduce in a second. But I'm just going to go through a little bit of housekeeping first. So hello, everyone. I'm Evie. I'm one of the co-organisers, and I'm going to be your host for today. So obviously, this is an online event, so there could potentially be some technical difficulties, but we are recording the talk. So if anything happens, then we'll be able to upload it later. So don't worry, you won't miss anything. There's going to be a bit of time at the end about 15 minutes for questions, which you can submit in a Google form that's in the bio of the YouTube video. And also, if you're comfortable with your name being written next to the question, then you can upload it to the live chat. And so it's an absolute pleasure for me to introduce everyone to Professor Duncan Cameron. He is a leading expert in sustainable agriculture. And in 2013, he won an award the World Economic Forum young scientist award, and was recognised as one of the forum's 40 extraordinary researchers under the age of 40. He has addressed the UN Paris Climate Conference on soil degradation. And not only does he have these incredible academic achievements, he's a gay and disabled role model at the University of Sheffield. And he's known university-wide for centering inclusivity in all aspects of his work. And so I will be turning off my camera and my microphone just to save internet and hopefully it will be okay. But yeah, other than that, I'll hand over to you, Duncan, start whenever you're ready.

Duncan Cameron
Brilliant. Thank you so much, Evie. Felt quite emotional actually hearing you say that. So hopefully, you should be able to see my slides now up if you could just let me know. So yeah, thank you for joining us today. I'm genuinely really honoured to be here today. I think Tanith, Evie, and the team have done an amazing job at bringing us a conference that's really celebrating underrepresented minority groups involved in conservation. And I think it's really important and a timely thing that we're doing.

So what, what the team asked me to do was to reflect on my career, and tell you the story of how my research career began, how I ended up in a refugee camp in Jordan, growing food in the middle of a desert, and what my research is going to try and do moving forward in terms of sustainable agriculture. So the talk's titled from Aberdeen, to xapuri from A to Z, a soil biologist's tale. So I'm going to talk about my PhD days at Aberdeen through to the work we did at Zaatari refugee camp. But to be fair, it probably should have started a little bit before A and in this case with S with the University of Sheffield. So I'm a graduate of the University of Sheffield, I did my first degree here in the mid to late 90s. So I'm going to tell you a bit of my story, and we're gonna have a whistle-stop story of the science that underpins it. So hopefully, I'm not going too quick. But I'll tell you about some of the key experiments that I think has shaped my career and got me to where I've ended up.

So when I thought about giving this talk, it was it almost felt a bit self indulgent to talk about me and my career. So I started to have to think about, you know, what is it about my career that's so important to me. And it's really the people that I've worked with, and the places that I've been so fortunate to spend some of my time and do my research. So the theme of my talk is really people, people and places. And the first person that I really want to mention to you is probably the reason that I'm sitting here doing this today. So our deputy Vice Chancellor and Provost, Professor Gill Valentine has been a real leading light in equality, diversity and
inclusion across the ag sector. And long before the ubiquitous rainbow lanyard existed, and Gill started the rainbow lanyard scheme and the idea of allyship, you know, well ahead of the curve. And it's because of her leadership that people like me, I think probably feel so comfortable being out and proud as gay academics in universities like the University of Sheffield, so I just wanted to say thank you, Gill. Because you know, you've made it so much easier to do this job, and to give this talk. So where did it all start? I guess in terms of research, I've pretty much had a lifelong obsession with the idea of symbiosis and symbiosis as a concept I think most of us recognise and it has a really simple definition. It simply means the intimate living together of unlike organisms. I was really fortunate in the final year of my degree, to go on a field course, with my tutor, the time Professor Mike Siva-Jothy. And Professor Ben Hatchwell, both who had been lecturing me on my degree in Animal and Plant Biology, here at Sheffield, we got to spend an amazing week, a field station called the Quinta de Sao Pedro, on the Atlantic coast of Portugal. And as part of that field course, we had the opportunity to go out into the landscape, and to look at the biology and start asking questions, asking questions about how that biology came about, how it was functioning, how it was regulated, what the physiology and the ecology of that of that biology might might be. And me and my team members stumbled across a group of aphids that were being attended by ants. And we wanted to understand why the ants were there is it's a mutualistic symbiosis, where both partners benefiting in terms of their fitness, from this symbiosis, or was one partner exploiting the other. And through a series of simple experiments, we're able to deduce that the aphids who where feeding on the plant, we're passing lots of very sugar rich solution in their poop. Now, that's probably quite dangerous thing. If you're an aphid, you don't want to end up drowning drowning in your own poo, which is made of sugar. And you certainly don't want to attract things to you that might might kill you like fungus that would take advantage of the sugar. So instead, the ants were taking away that sugar, and they were also protecting their aphid charges, they were always farming them for this sugar. And the two partners were benefiting: the ants were defending the aphids and taking away their poop. And the aphids were giving them a sugar rich resource that that they needed.

That was my first window on symbiosis. And when I came back from that field course, I was really excited, because I'd been offered a project, also on symbiosis, but a different type of symbiosis this time. And this was a parasite. And so parasite is a sumbiont that benefits in terms of its own fitness at the expense of its host who fitness is damaged by the presence of the parasite. And I was really struck by the idea that plants can be parasitic this this almost felt a really animal trait zoological trait, not something that plants did awfully often. And I was really inspired by Professor Julie Scholes, who lectured me as an undergraduate and a member of her team Dr. Anita Gurney, and and Anita and Julie offered me this amazing project trying to understand this parasitic plant. This parasite that the pretty pink flower is called the giant witch wheat A. harmonica. It's a parasite of Savanna grasslands in Africa. And it causes untold damage to the plants that it infects. And unfortunately, the parasite has entered agricultural ecosystems. And it destroyed the rice and maize and various other crops that were being grown in Sub Saharan Africa. And it's responsible for large numbers of people going hungry because it essentially steals their food. And Julie and Anita, were working to try and crack this problem, understand how this parasite was able to do this and see if there are any clues that that might give us about how We could stop it. And I was part of that project, which, I mean, Julie has just retired, but has really taken to fruition. And a lot of her work is now out in the field helping people suffering from hunger induced by this parasitic plant. And I got a bit obsessed with parasitic plants if I'm honest. And, you know, I really wanted to learn more about them. But I never imagined that I
was the kind of person that would that would do a PhD. I knew what one was. But I never thought that was that was to me. And wasn't until the finals were coming out. And I'd had an email, bear in mind emails were new in those days. So I'd not checked my email for several days from Mike Siva-Jothy, my tutor asking me if I would go see him. I thought, oh, gosh, I've I've cocked up my finals. This is not going to be good news. And in fact, it wasn't, I'd done really well, and I didn't particularly well in undergraduate projects. And Julie had spoken to Mike Siva-Jothy, you should nudge Duncan towards a PhD. So Mike, in his inimitable way, made it clear that I was capable of doing a PhD and I should look for one.

So I went to see Julie and her colleague, Mark and they very kindly pointed me in the direction of who would become my PhD supervisor, and someone that absolutely changed my life. So this is Dr. Wendy Seel. Wendy, is a plant physiologist, was working on a different kind of parasitic plant. And this parasitic plant was called the yellow rattle, R. minor. And she had a PhD going. So I tootled off up to Aberdeen for an interview, to study this parasite. And I was really pleased I got the job. And I met some really amazing people. I'll tell you a little bit about about these people and the context of the work I did in Aberdeen and the questions that we were trying to solve, and how this work took me to Germany and to China. And I should say, you know, I'm left with the mark of this parasite, because I literally do wear it on my sleeve. This is a tattoo that I have, which is a copy of a lithograph that Charles Darwin drew of R. minor. So I digress. Rhynanthus is, the yellow rattle, is a grassland parasite, it attacks, grasses, and herbs, and species rich Meadows all over Northern temperate regions of the world. And it seems to have a peculiar effect on those ecosystems. So if you go into those ecosystems, and you count up the biomass, or the numbers of grasses, legumes, and forbs, the forbs here are our broadly flowering plants, and legumes are flowering plants that can fix nitrogen. And if we focus particularly on the grasses and forbs, if you go and count them up in communities that have parasites, or have this parasite Rhynanthus or don't have it, the community seem to be really different, even if they're just next to each other. And so the parasite seems to suppress grasses. And that's a good thing because grasses tend to outcompete the broadleaf plants in grasslands, so they can often come to dominate and really restrict biodiversity. But in the presence of the parasite, these grasses are suppressed. And these forbs these these herbs, are promoted, and they can be promoted really significantly, you know, 50% 60% increases in the communities. In terms of the frobs present then. I mean, that's massive. And it led Rhynanthus being described as an ecosystem engineer. So we knew we could do this, we knew it could change the communities that it lived in. But we didn't know how it did it. And as a scientist, biologist, I wanted to find out, I really wanted to find out how this parasite did what it did. And they've been some such suggestions that it might be like a predator, it might be able to go out and hunt for a particular species. But that was difficult to imagine. And when we looked at that, we actually found the some of the papers that suggested that it actually suggested that it will preferentially attack the herbs the forbs over the grasses, but that didn't seem to ring true.

I thought back to my work with Anita and Julie and what Wendy had done, which was using a technique called histology. So they were looking at the interface between the host and the parasite. And this, this interface between the host and the parasites got a whole story. And you can think of it like if you've got a root, on the root, and the parasite root comes along, it grabs onto it. And it literally rips the root open and fuses its own vessels with that of its host, and it sucks its host dry. So by studying this interface, we can start to understand if some species, were maybe better hosts, because because the story was better able to get access to resources, and that was our original, original idea. And when we looked
at it, we found that the whole story formed by this parasite on grasses were totally different to those formed on the forbs. So in the grasses, they were big, they were chunky. And hopefully, you can see my pointer. They have these big kind of penetration pegs we call them that went straight into the host vessels and started sucking. But when we had a look at the forbs the history were really different, they were full of this black goo. And, you know, any biologist wants to know, I want to know what this black goo was and why it could be related to the forbs being really bad hosts for Rhynanthus. And Wendy had seen an advert for a conference, which is all about microscopy, and there's a talk being given by a chemist, he was using a particular type of spectroscopy. So she was firing lasers at tissues and using that to work out what they were made of. So Wendy booked me a place and told me I was going middle of the Aberdonian winter, I trekked out into the middle nowhere to go to this conference. And sure enough, this technique was phenomenally useful for me. So I came back I contacted the person who was doing the work, Allison Coats and she very kindly gave me the opportunity of working in her lab and analysing the chemistry of this black goop. And what this black goo turned out to be was a plastic that plants naturally make called lignin. And the chemical structure of this lignin was totally different between the susceptible grasses and the resistant forbs. And it became very clear that the chemical differences in how this plastic was put together was driving the the community-level effects of the parasite. So the chemistry of the plastic that forbs make is different from the chemistry the plastic that grasses make. And that means that when this parasite enters the community, it causes the community to change because it can compromise the plastic of the grasses, but it can't compromise the much harder and tougher plastic formed by the forbs. And this is a hypothesis that I raised. And it stood the test of time, in collaboration with my dear friends, Dr. Lewis Irving from the University of Tsukuba in Japan.

So my PhD finished, and I had to think about what an earth I was going to do next. And I was pondering that when Professor Ian Alexander, he was my head of department, most of the time as a PhD student, came into my office and said, Professor Sir David Reed, and Jonathan Leek, are looking for a new research assistant. And they need someone that can do the kind of chemistry you can do. So you should talk to them. And he's going to be here tomorrow. So I start with with Dave and we had a chat in the Botanical Gardens, and he invited me back to Sheffield, an interview, I was lucky enough to get the job. And this was working a different kind of symbiosis. In this case, that mycorrhizal symbiosis, often called the Wood Wide Web. I've seen a resurgence in that term in the press recently, and mychorriza are symbioses between plants and fungi. And they're near ubiquitous 95% of all plants that live or have ever lived form this symbiosis, and it's characterised by the exchange of resources. So plant fixes carbon through photosynthesis, it transfers that carbon into its roots. But carbon enters the fungal mycelium the fungal hyphae. And in return the fungus uses that energy to mine nutrients in the soil and transfer them back up and into the host plant. But a lot of the energy that comes out into those mychorriza also enters the wider food web and enters bacteria and small arthropods that exist in the soil ecosystem. This is a picture of what the mycorrhizal symbiosis looks like between a pine tree and its fungal partner. And the question that we that David had related to a different group of plants that seemed to have a bit of a strange relationship with mychorriza and they are the orchids. So this is the orchid, creeping ladies dresses. It doesn't look much but it honestly is utterly beautiful when carpeted it in front of you in a Scottish woodland. And orchids have a really weird lifecycle, they produce these tiny little dust like seeds. And unlike most normal plants, the seeds are so small that they don't have enough energy for the seed to germinate and make a seedling. So in normal plants, the mother plant would give energy in the form of carbohydrate to the the orchid seed and it would
use that plant feed it would use that to germinate but orchids don't do that, they give it virtually nothing.

So instead, they have to undergo a process called symbiotic germination, where the fungus comes along in the soil, it burrows into the seed and it starts giving it carbon and it produces these fungus-dependent seedlings are called protocols. And this is a process we called myco-heterotrophy. So fungus providing carbohydrates to these, these little seedlings. And these seedlings can spend years or even decades below ground before they undergo what's called a life-stage-dependent trophic switch. So they go from having no chlorophyll and feeding off the fungus to suddenly becoming green, and photosynthetic. And in some cases in evolutionary time, they've undergone what we call an evolutionary transition, and they stopped producing chlorophyll. Okay, so the assumption has always been that these orchids will be parasites that they would steal carbon throughout their lives. And there's some evolutionary quirk that means that they stop making chlorophyll as an adult because they don't need it. I should say the lifestyle complete with seeds that have typically around 100,000 seeds per plant.

So this didn't quite ring true why on Earth would the plant produce so much chlorophyll, and apparently be photosynthetic. So my job was to try and understand if it was possible to measure if carbon was flowing into the mycorrhiza. And lots of people tried it, some really good experiments were done, but no system quite cracked it. So I designed the system. With Irene Johnson, you have not put a photo up because she doesn't like having a photo taken, who is a senior technician in Animal Plant Sciences and one of my partners in crime throughout my career. And we designed an experimental system that would allow us to see the photosynthesis happening and flowing into the fungus. So we managed to do that in this paper. And what you see in front of you is a microcosm so a little tray, where we baited the fungus from the orchid roots out onto agar. And then we expose the plants green leaves, to a radioactive carbon dioxide. So just like normal carbon dioxide, the radioactive carbon dioxide was fixed. And we can see the plant is glowing with radiation. And we were then able to show that a substantial proportion of that was transferred about that photosynthesis was transferred into the fungal partner. And I think this was the subject of the first hate paper that was written about me by an orchid enthusiasts group. And that said, I'd ruined the magic of orchids by revealing that they probably weren't that much different from most other plants. And after the end of that position after the end of that postdoc, it was it was time with Dave and Jonathan's encouragement to branch out on my own. And to apply for a fellowship, and I was really lucky. I had two back to back fellowships, and some brilliant people. Some of them are on the screen now, that helped me through that part of my career. So the national environment Research Council gave me a fellowship for three years, and the Royal Society gave me a fellowship for another eight. So I was really, really fortunate to be able to do whatever I wanted in terms of my research for 11 years. And I was really fortunate because to the people in front of you, Dr. Janice Lake, and Dr. Heather Walker introduced me to a technique called mass spectrometry, which is a technique that essentially enables you to weigh atoms and molecules. And you can do some really cool tricks with that.

One of the tricks you can do is you can in the way you've fed radioactive carbon dioxide to a plant, you can feed carbon dioxide to a plant that is, is heavy, so it's 13 carbon instead of 12 Carbon normal carbon is 12. Heavy carbon is 13. And you can use mass spectrometry to find it. And there's another conundrum in these green orchids that we knew that they were Go through a transition to becoming to becoming parasites in evolutionary time. But we haven't really ever seen that happen. And it just
so happened that Sir David knew of a field site in Germany, where there were three species that were at different points in that evolutionary trajectory from, from being green compared simply photosynthetic, through to having no chlorophyll at all. And in between the two, there was an Orchid, the coral root orchid, coralirhiza, thryphida, love that name, which had no leaves, but still had chlorophyll. And we wanted to know why on earth, it would have no leaves if it could photosynthesize. So to try and understand how this evolutionary progression happens, we went out into the field and we expose the shoots of these plants to heavy carbon dioxide 13 C, across a range of different light levels. And we were able to measure the photosynthetic fixation of that carbon, and how that was translated into the orchid shoots. And, and what we found was a really interesting story, but our kind of leafy green orchids were expected was very photosynthetic. But our coral root orchid that was green, presumably photosynthetic, couldn't actually do any photosynthesis at all. So it turns out it was a parasite. And it was really these kind of techniques that got me interested in understanding the the wider function of plants and how they accessed their nutrients within ecosystems.

So this, this is a figure I've pinched from Ben-David and Flaherty from the Journal of Mammalogy, which is using the principle of these heavy isotopes to study trophic hierarchies. So the hypothesis goes that if you're at the bottom of trophic hierarchy, if you're a plant, you have a certain natural abundance in heavy carbon, heavy nitrogen. But if you get eaten, the organism that eats you, digest you, and it will preferentially use the light carbon, the 12 C and the 14 N the light nitrogen and the heavy carbon and nitrogen will stay in their body so they'll become enriched in it. So if a herbivore gets eaten by a carnivore, it will become much more enriched in heavy isotopes than than the bottom of that trophic hierarchy. And I wanted to in this fellowship to ask a question about a group of plants that that were very similar to the coral root orchids, and but they were green, but they didn't really have leaves, they had these weird little scales. And they were tiny, they didn't really, they didn't kind of look like they were able to fix much carbon yet they produce these huge fruits from from disproportionately big flowers. So I was really fortunate I met Jay Berlin, just as I started my fellowships, and we we've worked together pretty much ever since. And we were able to crack that question. And when we dug up some of these plans, we found that not only did they not have very much going on above ground, but they also didn't have very much going on below ground either. So they basically have no roots, how on earth were they getting what they needed. So again, we decided to see whether this idea of, of herbivores being eaten by carnivores, meaning that carnivores are enriched in heavy isotopes, would allow us to find out how much photosynthesis these plants were actually doing. And this was an idea that was getting traction in the plant science literature. And for two species that were very similar, they lacked real leaves, they lacked much in the way of roots, we were able to show that up in the top of both of these plots, that these plants were much more enriched in heavy isotopes than the communities that they lived in. So they were critically parasitic on the community by stealing carbon from mycorrhizal fungi. So, you know, we, we really start to tease apart the ecology of how plants interact with their mycorrhizas we thought they were all happy mutualistic, but no, the story is much more complicated. They can be parasitic. They can be mutualistic, they can be green, they can be not green, and actually the whole thing's very cryptic and confusing.

It just so happened at that point in my career, it was a lot of interesting mychorriza's in the context of sustainable agriculture. There are two really important people in my career at this point that really helped me branch out my and their professor Tony Ryan and Dr. Richard Summers, who are who's a commercial, academic and commercial scientist and head of
breeding RAGT Seeds. And I was really lucky because Tony Ryan had been following my work. And he'd recently had a donation from the Grantham foundation for sustainable futures. And the Grantham foundation had given him 50,000 pounds as a test donation to see what he did with it. So he, I don't know whether it's a great idea or a daft idea, but somehow worked. He came to see me and he said, Look, spend this 50,000 pounds on doing something for your career that will impress the Grantham Foundation. And I've been talking to Richard Summers, at RAGT Seeds, about building a project. So we use some of that money to sense check, an idea that we had about mycorrhiza. So remember, I've said that mycorrhiza, it's not, it's not straightforward. It's not obvious whether they mutualistic or not, it's a really complicated story. So, I'd had an idea from from work that I'd read, that maybe our agricultural, our management, of agricultural soils might influence how the symbiosis work.

So if you think about it, in the natural world, you're your victim to drought, your victim to nutrient stress, your victim to things trying to eat you, anything that gives you a benefit in that environment, it's a good thing. And so mycorrhiza's are probably really good, they help you take up more nutrients from the world around you. What happens if you put a plant in an agricultural ecosystem? If you give it all of the nutrients that it needs, if you stop anything from eating it, suddenly, the benefits of having this symbiosis to replenish your nutrients isn't so obvious. So why would you spend carbon energy on maintaining a symbiosis in an agricultural ecosystem, when you don't need it? When a farmer is doing it for you. So I hypothesise then that lots of different wheat varieties that we had bred in this circumstance should vary in the extent to which they form mycorrhiza, depending on how intensively bread they are, there were lots of different factors, but there should be huge variation. And that's exactly what we found, we found that different wheat varieties could do really well forming mycorrhiza to the high end of this graph. And at the low end, there were lots of varieties that were more modern, not exclusively so, but more modern, that really couldn't find mycorrhiza at all, which could be a problem, it means you're gonna have to fertilise them a bit more. But I also had a bit of a, an idea that maybe mycorrhiza did more than just give plants nutrients. You know, you have the old adage that if your environments too clean, then your immune systems not going to be very good. But it turns out the same is true if you're a plant. If you've grown in a sterile environment where you don't have many mycorrhiza or you can't access those mycorrhiza, then your ability to defend yourself in terms of your immune system being activated is reduced. So we did a simple experiment where we took a wheat variety, we related it with a mycorrhizal fungus or not, challenged it with a pathogen with the eyespot fungus. And the results really startled us. We showed the the the plants that are mycorrhizal could fight off this infection. But the plants that didn't have the mycorrhizal fungus where we're totally, totally decimated really by the eyespot fungus, you can see producing these horrible lesions that eventually cause the stem to rot and collapse.

And at this point in my career, I'd I've met another academic and other early career academic. Now Professor Urian, Tom, he's become very close friend. And I told him what I was doing. And he said, Well, that's uncanny because I work on how the environment can induce host plant's immune systems. But I'm interested in bacteria. I wonder if there's a relationship between the two. So we did a series of thought experiments, and it kind of made sense, but actually, you know, we know that plants send signals out into the soil to get hold of their symbionts. And we know that some of their signals are very similar for bacteria and fungi, and some of them are very different. And what we hypothesised though, was the plant very strongly signals for fungi when it's very young, and also for bacteria. And if it recruits a consortium of fungi and bacteria into its roots, they
could essentially have a double whammy effect on activating the immune system of the plant and getting it ready. Like an immunisation really like an injection. ready to fight off infection. So we, we were talking to another close friend, Dr. Alex Perez DeLuca. He was looking for a fellowship overseas. So he applied for some money from the EU. And Alex came and was able to demonstrate that these thoughts were indeed true.

That's a bit of a whistlestop tour of what got me to the point of my my real true obsession, which is the most unglamorous I think of all of the world's ecosystems. And that is the soil. And I think this this, this quote is sent to me that that really made me kind of reflect on how important the soil it's. And this quote is, despite all of our achievements, we owe our entire existence to a six inch layer of topsoil and the fact that it rains. That's quite profound really when you think about it. And that's why we exist, that's how agricultural works. Without it, we wouldn't be able to feed ourselves. And we know that soil is a limiting and non renewable resource. We're losing vast swathes of it in the 1930s, in the Midwest of America, over exploitation of the soil, and over ploughing of the soil completely stripped it of all of its structure, its carbon, its microbiology, and it meant in a period of drought, and some intense wind, the soil literally blew away. And that led that then President Franklin D Roosevelt to write to all of the governors across the states. And in that letter, he said the nation that destroys it, soil destroys itself, yet we've kept doing it. So we probably lost a third of our agricultural soils in my lifetime, in the last 40 years, that really troubled me. And we can see the damage that agriculture can do to soils. Just from the experiments, this is a piece of work that one of my closest collaborators and friends Jonoathan Leek did with a master's student that we followed up with a couple of rounds that we had, we did really simply expand he got soil from a transect. So a straight line out of a woodland through a hedge, a grassy margin, and then two and 32 metres into an agricultural field. And at the top of this pitch, you can see a plan view of what the soil looks like. It goes from a nice dark crumb soil under the hedge to concrete 32 metres into the soil. And that's reflected in a 70% loss in the biomass of the wheat plants that are grown there. So in growing our plants, our crops that we depend on, and soils that are so denuded of the resources that they need to support both crops that we use 70% of growth. Now, that's startling. And that sort of disappearing, like I say, you know, over a third of our agricultural soil gone in my lifetime, and you can see it happening, you know, this is a storm event two years ago. And all the brown around the UK is soil bleeding out of the rivers and estuaries. And that's lost, you know, it can take up to 1000 years to produce a few centimetres of topsoil under normal agricultural conditions. And something was happening at this time. Where we, we know that agricultural productivity was starting to slow down. So from the 60s, up until the 90s, really, we were producing linearly more cereal year on year. But now it's late 90s. Something changed, and we were struggling to get more cereal crop out of our soils. And I started to wonder if this is because so functioning had been, had been affected. And I took my evidence, I synthesised it into a policy review, which suggested how agriculture could be changed to make it better. And I took that to Paris. Tony Ryan had been invited to the Paris climate negotiations, he took a team of us where we presented our evidence to the the assembled people, so it could be included in the discussion process. And it was, to my surprise, it was really championed by the press and on the front page of The Guardian talking about how unsustainable soil loss was and how we needed to do something about it. And I also experienced my first backlash and put my head above the parapet the first the first attack, well, two attacks from well known right wing news websites via Twitter. These tweets now been deleted, but I have my screenshots that describe me as another peddler of University disaster pornography. And one commentator questioned that they couldn't help but question the objectivity of a liberal
homosexual English professor. I was quite enraged by this, as you can imagine, I remember sharing it with my family and my father said well that's ridiculous. You're not English, you're Scottish. And that puts it into context. And that really started my interest in the wider issue of food security and food insecurity. And I started working with Peter Jackson and Peter Horton, who taught me, plant scientist Peter Jackson, celebrated social scientists, on this on this problem of food security and how lands and crops interacted with the wider picture of food production. This is often how we think about how food is produced from lands through to consumers buy a food, and it's very linear Farm to Fork fashion. But when we actually look at what our food system looks like, it's more like this. It's wrapped in all of these complex externalities that regulate how land becomes crop becomes product becomes huge, becomes something eaten and consumed by consumers. And we wanted to try and understand and map how these kind of supply chains would function.

This is when I met Professor Lenny Koch. And we work together on a piece of work to try and understand how bad for the environment something simple like a loaf of bread was. And in that piece of work, we showed about an 800 gramme loaf of bread had nearly 600 grammes of co2 in it. So it produced nearly 600 grammes of co2 from planting the seed something to taking that bread off the supermarket shelf, and staggeringly 43% of that came simply from the use of fertiliser. So it made us realise that we could use these kind of methods to understand how agricultural systems work, and suggest something more sustainable. And that's sort of the idea for the microcosm farm came in. Tony, my colleagues, Jake, Harry, Mark Sinclair, and colleagues from Soho University, Raj, were at Marrakech cop 22. And we came up with this idea of what can we make this more efficient? By making a farm in a box? Could we replace the soil with something else? So we're not degrading? So could we use pure Lee green power to power our farm. And the idea for synthetic soils was really born, we recognise that we could and actually saw was one of the things that are limiting agriculture and sustainability of agriculture, if we could make a soil out of something that we could recycle and reuse, that would still behave like a soil, then that would really help contribute to the climate crisis into the sort of crisis. And it turns out that if you modify the chemistry of a car seat, you can behave even make it behave remarkably like a soil. So mine in Tony's pitch is you Harry did that piece of work. We took it out to so high University, in Oman. And we were able to show that actually this farm in a box worked for us the synthetic soil, we really could produce lots of food very cheaply and very efficiently. And we realised that we could bring that technology back. So we brought the synthetic service back to Sheffield. And we we built a community farm intensely that Jake led working with lower socio economic groups and producing food with them that they wanted to eat a price that they could afford, which was a really exciting piece of work. And actually, that project really spiralled when we recognise that using that technology, and this is a piece of work led by my friend and colleague, Jill Edmondson. But we had lots of space in Sheffield, where we could roll that technology out lots of flat roofs to tissues, buildings. So these kind of community farms could really contribute significantly to the amount of food we need to produce. But it also brings us to the last example that I'm going to give, which is how we ended up at Sachi refugee camp. So all this work on synthetic soils really had a had its biggest application in this actual refugee camp in Jordan is actually his home to refugees from the Syrian conflict, which many people have forgotten about. It's one of the biggest cities, towns cities in Jordan, and it's in the middle of the desert. And this chap, my very dear Friends mode on this money had been working with me for a long time.
He's a refugee from Syria, and a very senior biologist. When he was back home in Syria, he came to Sheffield through the scholar rescue programme, and work with me with Julie Grey in the biology departments. And while Mohed was working with us, Tony have been invited over to the factory refugee camp by his friend and story to see if they could, if they could practically do anything to help if they could co-design solutions with the local population to problems that they had. And I got this incredibly excited text message from Tony, that they were super excited in Zaatar refugee camp about some of his ideas. But they weren't allowed to plug things in the ground. But they have thousands of old mattresses, tomatoes, here we come. And he sent me this picture of using mattresses as synthetic oil. So I said well get some, which he did, with the aim to restoring the colour green to Zaatar camp. Because when Tony spoke to the population, that's the thing, they missed the most of the colour green in this very monochromatic environment. So Tony grabbed a mattress, and he got his Zaatar mattress foam. And it came back to Sheffield. And we designed a series of approaches that allowed us to produce a pretty decent tomatoes. We met this amazing chap, green hand man who, with Mohed's, hydroponics skills and fluency in Arabic, and the work that we've done between Tony and my labs in Sheffield, we were able to take the protocols back to Jordan, and the green beds project was born. And it started off very small and grew. And you can see the projects that was being being grown with it. But we knew that the project needed support. And I think I've completely overwhelmed when I checked this a couple of days ago, that we've nearly raised through our appeal to keep this work going a project jointly with the United Nations over 230,000 pounds to secure the future of the desert garden. So where do we go now? Well, my work is taking me into new and different places. I've spent time in Australia. Working with Julia, and our work with recently our ideas are recently published in the WWF Living Planet report on making connections from land to sea, what happens if you use crops to feed fish in aquaculture? And I can leave you to read that if you're interested. And can we actually take the synthetic soils and its disease suppressive microbes? Can we take that from concept lab into commercial norm, and one of the people have not mentioned thus far is Professor Tim Daniel, an old friend and collaborator, who I'm working with, along with all of these other people to take that science into application jointly with commercial partners. And the final thing to say is the Institute for Sustainable Food, I was going to show you a video I don't have time now. But please check out our website and have a look at our video about the Institute for Sustainable Food. Where we're doing lots of things like this is not just about me and Peter, it's about a diverse community of 150 people that are aiming to make food, the food supply more secure for everyone. So I guess I'm gonna leave it there and say, you know, today's talk was was really about people and the people that have shaped my career. And I've been so fortunate and honoured to work with. So I'm going to leave their faces up now. So thank you very much to all of you. If you are interested, check out my website or follow me on Twitter. Thank you very much.

Evie Croxford
Thank you so much, Duncan, that was so brilliant. And so fascinating. So we've had a fair few questions come through. So the first one, from a soil health perspective, do you know how organic farming fares?

Duncan Cameron
So organic farming is very good for soil health, it's not very good for people. So organic farming is usually very good for soil health, because it's all about getting carbon back into the soil. But in the absence of using agrichemicals and some are bad, some are good. You know, the the yields are really low. So if there's ever an inequitable way to produce food, then it's and it's to do it organically. I'm not saying it's all bad
because I think some of the principles of organic farming and brilliant and I went on record a number of years ago that landed me in hot water and on the front page of the metro with the title from crap to crop. When I suggested that the farm of the future should use GM principles, GM technology, organic principles and human waste to fertilise our food. And if you check out my website actually did a children's kind of panto type lecture, which is called everyone's a fertiliser factory, which is all about the idea of using poo to grow food.

Evie Croxford
And so another question that we've got is, what are your thoughts on the 2019 to 2021 agricultural bill in the UK?

Duncan Cameron
I think, mixed. I think it was a golden opportunity to set out an agricultural set of agricultural policies that would reduce carbon dioxide, support and empower our farmers and protect Food Standards. And I think I'm really disappointed that our government has failed, you know, if there's, I'm an ardent, ardent remainer. But if there's anything good that was to come out of Brexit, it was to get rid of the Common Agricultural Policy, which was a lazy and dreadful piece of legislation. We lost that opportunity. Because, you know, we haven't thought deeply enough about public payments for public goods, how we support farmers, and pay them as custodians of the land, to farm in environmentally sustainable ways, rather than force them to degrade their land. You know, farmers, farmers have phenomenal resource, intellectually, and from their own experiences. And I don't think they're championed enough in this debate. I think, you know, we missed a massive opportunity to support them to learn from them, and to make our food system more sustainable. And we haven't given up, you know, I spend a lot of my life giving evidence to committees lobbying, government, doing reports for debt for, and I think people are starting to listen. But I, I'm disappointed that that we didn't, that we didn't really grasp that opportunity in the way we could have done.

Evie Croxford
next question we've got, are you worried that the use of synthetic soils may de-incentivize investment in soil restoration projects?

Duncan Cameron
That's a very, that's a really, really good question. I'm not because I think we've we're at a crossroads. So in the UK, most of our horticultural production occurs in soil and under polytunnel and grassland, and most of it occurs in England, at least on the peat rich, carbon rich soils in East Anglia, which are degrading at the most phenomenal rate, you know, the, we need to take pressure off those soils. And we need to make that solution the cheapest and simplest solution to move away from using that kind of agriculture on those soils. And I think that's where the kind of technology we're developing comes in. It's not just for electric daisies in urban farms that feed posh restaurants. This is about making it really easy and cheap and safe to produce food. And the idea of bringing nature into these controlled environment farms using synthetic soil in the form of disease suppressive microbes, using these recyclable soils. I think if it's done with the correct the correct partners that we're doing it with one of the levee boards that represent farmers, the HDB, then I think it's got a really good chance of doing good rather than doing bad but but but it's absolutely true. We always run that risk when you deploy a new technology that you deincentivize current good behaviour. And I certainly hope that we won't do that.

Evie Croxford
when the crop is harvested can the mattresses be reused to grow future crops, that's from Rosie Dunkley.

So again, a good question. Yes, they can say we can use the mattress foam several time we can use the foam that we produce for our synthetic soils several times we've done a simulated crop of 10 seasons thus far and it gets better with time which is really interesting as it becomes enriched in carbon so i think you know there's lots of there's lots of really, you know, there's lots of lots of cool stuff going on.

Duncan Cameron
Great question. We don't know, and I suspect Probably not. You know, there is never a magic bullet in agriculture, there is not a technology that will solve everything, I think soil it's probably best for root vegetables. But I think salad vegetables and vegetable fruits are probably best produced in a hydroponic, in some some cases producing these kind of planning systems. That will depends on where you are and what sources you're growing on. And, you know, the the market prices and cost of producing those food, I think hydroponics is really easy. If it's if it's done, like we did it using recycled materials in a refugee camp, it can be very cheap, it's really easy to learn the technology to do it at home. So I think it democratises food production at home as well, where if you don't have land, or if you live in the city and you have a yard, then cheap hydroponic system is very, very affordable. And Jake is doing a lot of work designing hydroponic systems that people could instal at home. He, he runs the Red Deer pub, as well as being a research scientist. I mean, he has a hydroponic wall in his garden growing food to show you that you can do it. made of recycled bits I should add,

Evie Croxford
um, do you implement the FWE Nexus concept into your methodology?

Duncan Cameron
So I guess by by that they're talking about the food and the energy food, water Nexus. Is that right? Yeah. So yeah, we we've very much been involved in Nexus thinking. We we've had colleagues at Sheffield, Leeds bsfc Nexus project, I think Nexus thinking is all about understanding trade offs, and understanding potentially perverse outcomes of probing the system in one place and it responding badly. And another. And that's one of the reasons that I work with with Lenny. Also with Rachel Rothman, who is head of sustainability for university, absolute sustainability superstar. She, myself and others have been using these LCA, these lifecycle assessment, modelling approaches to embrace that Nexus thinking. So saying, right, if we shot the system here, what might what might it do? Where Where might the perverse outcomes be? And the work that I'm doing with with Julia blanshard, in Australia, she's a globally leading mathematical ecologist. So she builds mathematical models of these food production ecosystems. That means we can say, right, if we divert a crop from land, turn it into fish feed and put it into the sea to grow famine, what might be the trade off where where might that system caused more environmental damage, than then it would reduce environmental damage as well. So very much embracing the idea of Nexus thinking.

Evie Croxford
I think this would probably have to be the last question asked, how would you recommend getting into soil science post degree?
Duncan Cameron
So I think, I think there are lots of ways of doing it, you know, I was really, really lucky that things kind of fell into place for me. And I didn't realise how obsessed and interested in soil I was, there admit that until I was quite a long way down the road. But I do a lot of work with community groups with schools. And I think volunteering and learning more about it is a really good way of building up a skill set that's going to make you incredibly employable either for a PhD or in the sector. So working with local groups who groups like regather, in the Shffield food partnership, for example, food cooperatives is a really good way of learning about soil getting experience with farmers and food producers. And that really set you up for a career in in sustainable agriculture. Whether that be in research or otherwise.

Evie Croxford
Great, well, yeah, we have to finish this now. I just want to thank you again, Duncan. It's been so interesting and laughing getting a bit emotional at some points through so fascinating to hear your story. And, and to everyone watching, please tune in at the same time tomorrow. We've got Dr. Yoselin Benitez-Alfonzo, talking about her career, and she specialises in plant cell communication. So don't miss that. Okay, thanks, everyone.

Duncan Cameron
Bye