Floodplain Meadows Partnership Conference

14 October 2021

Day Two Session 1 9.30 – 10.20

Emma: Good morning. It's 9.30 so I think we'll make a start. I'm sure a few more people will join us as we go through. Welcome to Day Two of our Floodplain Meadow conference. For those of you that didn't join us yesterday evening we had a very interesting session. Just as a point of admin, all of our sessions are being recorded but it may take a little bit of time to get them out after the conference because the footage will need editing and captions adding in so please bear with us with that, but they are being recorded. Before I hand you over to our Chair and our speakers for this morning I just wanted to make a couple of admin points. Just a bit about the biographies in the programme, some biography links go back to personal pages or where people didn't have personal pages there's a single document that lists the bios in alphabetical order by surname, so just scroll down and find who you're after. After yesterday's experiment with videos I have uploaded the site visit videos to YouTube and I'll post the link in the chat. If you can't see the chat can you email me and I will post you the links separately. They're really well worth a watch if you didn't manage to get them. We have a conference hashtag now, which is #FMPConf2021 which I will post in the chat and we'll be using on Twitter. Finally, I know that there are some people who are struggling to join the chat but can see it, we're not entirely clear why that is. You could try, if you haven't done already, leaving and coming back in again, this does some work. If you're using a web browser, it might be worth trying to download the app but I appreciate this might not work for everybody. So I'm just really sorry about that. If you have something that you want to put into the chat, even though you won't be able to see it, you can email it to me and I will post it for you. My email address is emma.rothero@open.ac.uk. So I'm now going to hand you over to our Chair for this morning’s session who is Sue Dancey. Thank you very much Sue. Sue has worked for the Floodplains Meadows Partnership since 2008 whilst she was working for the Field Studies Council as a Biodiversity Learning Manager. She is now an active volunteer with the Botanical Society of Britain and Ireland, the Shropshire Botanical Society, and People Need Nature. Her interests lie in training and education. So I'm going to hand you over to Sue.

Sue: Good morning everybody. It's lovely that we've got so many people already, over 70 people joining the conference for Day Two. I'm not surprised really because when you look at the list of speakers and presenters, I think we're doing incredibly well to get so much knowledge of soils in our day. I think it's so important when you consider that soils are literally the root of everything aren't they and our floodplain meadows just wouldn't exist without the soil structures that we're striving to help and their hydrology is, of course, particularly important. So we're looking at them from all angles today and you'll see that we'll have an introduction from our first speaker, who is David Gowing. This is a video link for us. So he's done a pre-prepared one for us.

He'll give us the context of soils and our floodplains and from there we'll build up so learn more about how important this resource is. So thank you very much everybody, and over to Professor David Gowing who's from The Open University. Now his Professorship is in Botany, but he happens to be an expert in soils as well. So we're very lucky to have that.

David Gowing Soils of floodplains - video

David: I’m in a floodplain meadow just outside Milton Keynes managed by the Parks Trust. In fact we're using this site as part of a cutting experiment hence the vegetation at different heights. Today we're going to look at what's beneath our feet and explore the soil. So to understand the soil we need to look at the profile and the easiest way to do that is with something called a gouge auger which is what I have here, sometimes called a Dutch auger. So we're here in mid-September and the soil is pretty dry so it's going to be tough to get started. September-October tends to be the driest period of the year for soils. Here's the topsoil with a little bit of litter, a lot of root so the auger will continue to take small cores like that out. It's important to bend the knees to lift the auger and pull it out with your legs not your back. Again more dark brown soil absolutely full of roots. Then we can continue to do that right through the profile. Over here I have one I've done earlier, so we are about 85cm down and I've stopped because you might be able to hear I've hit stone at the bottom and that’s the gravel layer. I've laid out the profile that I took from this hole. From the graphs at the top, A horizon, B horizon and at the bottom you can see we have pieces of quite large gravel that has stopped the auger going deeper. So once we have the soil profile, there's a range of characteristics we're interested in. People often talk about the texture of the soil. So if we take a little bit and wet it up, and then rub that slurry between our fingers and then by rubbing that between your fingers you're able to sense the composition in terms of clay, silt and sand. Clay feels particularly sticky. Silt feels slippery like soap, and sand feels gritty. So just feeling this sample, there’s definitely clay in there, it's feeling sticky, but also quite a lot of silt. It's very slippery. So I think we'd class this as a silty clay. So that's the A horizon which is perhaps 35cms deep. Then we move into the B horizon, slightly different colour, mottled orange and grey that we will come to later. If I now try and texture that, it’s really very similar, possibly a little more clay, it's a little stickier, but still plenty of silt as well. No sand. So texture-wise it's still a silty clay, there hasn't been a great change between this A horizon and the B and then at the bottom we have the gravel. The more important thing from a management perspective in terms of understanding the water regime is the structure of the soil. So here you can see very much a crumb structure, the soil has organised itself into aggregates a few millimetres across and they're very stable in these old meadow soils, they're glued together by organic compounds and this really has effectively the texture of a coarse sand or even a fine gravel in terms of water moving very rapidly through it. So this is the A horizon that's got plenty of organic matter in, then we move down into a B horizon which does not have such a fine structure. I should say it is difficult to talk about structure too much where you've pulled it out with an auger because the auger tends to collapse the structure and the

B horizon there's probably still some good macropores and fissures that allow water to move but it's slightly less permeable and then down into the gravel, that has no structure as such, but again a lot of porosity, a lot of permeability for water. So another difference between the A horizon and the B is the colour. The A horizon tends to be a warm brown orangey brown colour whilst when we get into the B horizon if we break some of these units open we can see a mottled effect of quite a bright orangey brown and a bluey grey colour. These colours are reflecting the oxidation state of the iron in the soil where orange is the oxidised form, the ferric salts and the grey is the reduced form, the ferrous salts. The reduced salts form by bacterial action when the soil is saturated and there's no oxygen available, whilst the ferric salts develop when oxygen returns to the soil. So where you get this mottling with both colours it indicates that the water table is moving up and down this profile, and you're getting periods of anoxia, without oxygen, and then periods where the soil is aerobic. So we can just by looking at the colours say something about where the water table is and for how long. As we go lower in the profile we expect to see more of the grey colour though here because the texture is beginning to change now, and you can feel the grittiness of the sand that complicates the colour story. So the gravel is sitting in a matrix of sand which is very permeable.

So in terms of actually quantifying the water regime, we can use a hole like this one we've just made to install a dip well. A dip well is simply a piece of wastewater pipe that's drilled at regular intervals and that will slot into a hole to keep it open. Typically in a meadow we would saw it off at ground level and put a plate on it to protect it from vehicles and stock. Then using a graduated staff like this we could regularly revisit and measure the position of the water table. We call this a buzzing stick because when it's in this case hitting the bottom of the hole you get a beep. It does the same when you hit water. But this profile at the moment is entirely dry. So a dip well is as simple as that, costs just a couple of £ to cut and drill a piece of pipe and then that will stay in for years if needed.

So another thing we can look at with this profile is the rooting depth. The A horizon is absolutely full of roots but as we look down we're getting to 60-70cms there are still distinct roots in the soil showing the depth of grassland rooting and the roots will reach right down to the gravel layer which is how the plants take up the water but they also are pushing carbon down from their tops into the soil as root exudate and that carbon accumulates through the profile so that the darker brown colour near the surface is where most carbon sits but it's a feature of these alluvial soils that they have carbon throughout the profile and so the total amount stored can be very considerable. Another feature of these soils, as I've said, is the extremely good structure which means they can be as much as 50% pore space so these aggregates have pores between them and that can represent more than half the volume of the soil which makes them conductive to water and able to store a lot of water. But that porosity can easily be lost by compaction. At this time of year the soil is so dry that you can't really compact it, it's really quite strong. But this site is grazed later in the year which is fine, the cattle won't do any harm to the porosity either until the profile is wet up perhaps by Christmas or New Year it will become soft and it's at that point it's important to remove the stock to protect the soil.

So before we go, it's important if we weren't using this as a dip well to refill your auger hole and to return the soil in the order it came out. So that is the first look at the soil here using the auger and if necessary the dip well to get a feel for what's beneath our feet. There's a lot more that can be done. So samples can be taken to look at the fertility of the soil, exactly how much carbon it holds, as I mentioned the porosity of the soil. A lot of additional work could be done depending on what the management challenges are. But the important things we've seen today is this field has a very well developed A horizon, very well structured suggesting it's never been ploughed and it's been well looked after in terms of no vehicles or heavy stock on while it's wet. We didn't see any signs of compaction. We also saw that there was a clear gravel and sand layer at the base and that's very important for the hydrology. The water will be moving off the valley sides and towards a stream in the middle of the field there that acts as a drain. So it's a permeable soil over a gravel aquifer, so perfect conditions hydrologically for a species-rich floodplain meadow.

Sue: Thank you to David. That was a lovely presentation on the instruments used to examine the soil structure and we're now able to take our understanding of soil a stage further with Clare Lawson who's going to share with us how soil carbon is stored in our floodplain meadows. Clare is a lecturer from The Open University working in the same department as David and it's great to have her on the Floodplain Meadows team.

Clare Lawson Soil carbon storage in floodplain meadows and Ecover ‘Fertilise the Future’

Clare: Thank you Sue for the introduction and yes, and also for highlighting that actually there are a lots of other colleagues involved in the presentation that I'm going to give today. So even though it's my name up there, there are plenty of other people involved. So we all recognise that floodplain meadows are vibrant and colourful sites and they are highly valued really for their wildlife but also landscape and history. We know that they were once very widespread and we've got a later session in the conference looking at the historic coverage of these species but as has already been mentioned yesterday that it's one of the rarest grassland types left in the UK and it's thought only about 3000 hectares remain.

So we obviously recognise floodplains. The clue, as Tony Juniper said, is in the name that they are very good at regulating flood events and they provide that essential space outside the river channel for the floodwater to spread out into. However we know that they do provide many other benefits. We rely on these floodplains for many environmental goods and services. So this is really where food production, biodiversity, carbon storage, the rich cultural resource that they are. So really these floodplains are multi-functional landscapes.

So I'm just going to briefly highlight some data we presented of some work that we did for the Valuing Nature Natural Capital Census Report where we looked at the extent of different land use types based on the CEH Land Cover Map within the Flood Zone 2. So I think there was a question yesterday about how much the 70,000 hectares priority habitat extents that restoration we're trying to look at really, and that covers probably about 10% of this Flood Zone 2. So it's quite an increase, because you can see that neutral grasslands at the moment covers a not very high amount, and that covers all the different types of neutral grassland. But as you can see here, both arable and horticulture and improved grasslands nearly cover 70% of the current Flood Zone 2 within England and Wales, obviously slight differences between England and Wales in terms of arable and grassland. So what we're really interested in is looking at comparing this to the other semi-natural habitats as you can see that woodlands and other habitats are really quite poorly covered within the floodplain. So as a total they're about 10%.

So as we've heard about that soils are a major carbon store. They are the largest terrestrial pool in the UK, about 95% of terrestrial carbon is stored in the soil, so they provide a very permanent store. But if we look at how much carbon is stored within these different habitats, and this is data from the Countryside Survey Report, we can see that the density of carbon within arable and horticultural soils is much lower than improved grassland but it's also much lower than other habitat types under these broad land use types that CEH categorise. But if you look at the area of land use within the floodplain, the actual stock is much higher just because of the area of arable and improved grasslands within the floodplain. But obviously if you increase the areas of the other habitats within the floodplain then the stocks of carbon would increase enormously.

So here I'm just going to introduce some other work that I did as part of a Daphne Jackson research fellowship. So as we can see from the Countryside Survey data, grasslands can be a very effective store of carbon. But what we were really interested in in this was looking at how much carbon is stored in the soil of these actual floodplain meadows. So I went out to 4 species-rich meadow sites and we sampled the soil down to a depth of 50cms, so beyond the A horizon that David mentioned. We also did look at both the pH and the phosphorus and we did botanical data collection as well for the soil samples.

So these floodplain meadows support a huge range of different plant communities. So they have the dry alopecurus pratensis, sanguisorba officinalis grassland, the typical MG4, but going right through to more inundation grasslands. So it's just to show that these meadows support this mosaic of different plant communities. But what I'm just going to report is actually just site characteristics. So this is work for later really. So yes, we sampled at 4 sites, many of these will be familiar to you. So

Cricklade over at the Upper Thames, Yarnton and Oxey Mead near Oxford, and then Port Holme which is on the River Great Ouse near Huntington.

So here I'm just presenting the total carbon in these soil profiles from the different sites. We haven't yet got the data for the lab to look at the inorganic components. So in these samples, it represents all the carbon in soil, but some of that will be locked up in maybe calcium carbonates. So this is the really preliminary data. Here I've separated them out by depth and you can see that the shallowest profiles, so the 0 to 10cm profile, very much the total carbon is much higher in this, and it does decline throughout the profile. But as David pointed out in the previous video, there is still quite a substantial amount of total carbon down in that lower part of the profile, the 35 to 50cm part of the profile.

So here we've got a slide showing the diversity and depth of the root systems that we see in species-rich floodplain meadows and this helps really explain how grasslands are really able to sequester that carbon at depth. David showed you the roots down to quite a depth in the soil profile in the video before it hit the gravel layer. But some of these plants species that you find in typical floodplain meadow communities can reach a rooting depth of up to 2m. So where you have these species-rich mixtures they have these very diverse root systems and they can occupy the space beneath the ground allowing them to lay down this carbon. We think it's this diversity of root forms really and the occupation of the soil that help that fixation of carbon throughout the soil profile in these floodplain meadows. I'd just like to highlight that colleagues, Vicky Bowskill and Irina Tatarenko have done this fantastic drawing.

So how do species-rich floodplain grasslands compared to other habitats? So this is going back to the data from the Countryside Survey, and I said previously where I presented data from the sites that it was just the total carbon, but for one of the sites for Cricklade, North Meadow, we have actually been able to do the work where we've looked at just the organic components of the soil and also looking at the bulk density because the bulk density will vary between these soils. So it's actually being able to take it from a percentage to a tonnes per hectare. Just from data at North Meadow in just that top 10cms, the data that we have suggests that there's about 110 tonnes per hectare of carbon within the top 10cms and you can see that this is much higher than those broad habitat categories. So the caveat on this is this, this is just from one site. We will be working up the data from the other sites, but it's just to show that just in that top 10cms, so there'll be even more going down the soil profile, there is a very high carbon store within these soils.

So we're also carrying out further data collection in another project with partners from the Berkshire, Buckinghamshire and Oxford Wildlife Trusts and also Long Mead and Catriona was in one of the videos yesterday, and I think is talking later. So this is the Fertilise the Future project funded by Ecover where we're looking at the different land use categories up and down the Thames to the west of Oxford, which you can see in the map there. So we're looking at the carbon stored in these 4 different land use types. We've just done the 1st year of data collection. These results are very hot off the press. I got them on Monday. But again there's a bit of a caveat involved in them in that they are just one site. So there's 1 species-rich site, 1 site over 10 years, 1 site under 10 years grassland restoration, and the arable. So we've got a lot more data to come with this. But as you can see here the species-rich site has quite similar total carbon results to the other sites that we've previously sampled. So at Cricklade and Yarnton. Then the restoration sites in the middle where again they've got less carbon in them but if you compare them to the one arable site, you can see that there's a large difference in the total carbon between these different land use categories. You can see here that it's actually throughout the soil profile right down to the 35 to 50cms that is depleted within the arable soil. So yes, these are just presenting 1 site so I'm really hoping that as more data comes through from the lab these results will be strengthened.

So really the future work and opportunities for floodplain meadows, what we really want to do is expand the evidence base for carbon storage in floodplains. We will be really looking to try and feed the data that we're collecting into updated versions of the Natural England Carbon Storage and Sequestration by Habitat Report, as this report really highlighted that there were quite a lot of evidence gaps. So it made these figures really difficult to assess in the existing literature. So that's what we're really hoping to add to. Also looking at the diversity of the different plant communities within the floodplain. So we've looked very much at the MG4 but also concentrating on different plant communities as well. Then as David mentioned in his talk, hydrology. But again just looking for further evidence, it’s really what restoring these species-rich floodplain meadows can do for us in terms of carbon biodiversity, just switching from arable farming to grassland within the floodplain could really increase the amount of carbon in the soils and its recognition of this value of this species-rich permanent grassland in policy that that we're looking for. Anyway, thank you very much.

Sue: Thank you very much Clare. There was some fantastic graphics in that talk that just show us how amazing floodplain meadows are at keeping carbon and that's something that I know that we're lobbying for because planting trees isn't everything is it in making sure that we've got our carbon sorted out. So thank you for demonstrating that so well. We're going to go on now to our 3rd talk of the morning. This is looking at a slightly different dimension because obviously life in the soil is not just about plants. Although some of us would like to think that's true. What we're really looking at is the animals who live below the surface that keep that soil even more healthy and productive and we've asked Simon Jeffery to come along and tell us all about this. Simon is a reader in Soil Ecology at Harper Adams University, which is up here near me in Shropshire, which is a fantastic university in terms of informing agricultural practice, so now let's go over to Simon.

Simon Jeffrey: Microbes in the underworld and their function within floodplains

Simon: Thank you very much for that introduction and indeed thank you to the organisers for giving me a chance to come here and talk about an area that I conduct some research in and that's basically the area which exists underneath your feet. So I'm going to introduce you to this world that you've spent quite a lot of time in close proximity to, but probably not spent an awful lot of time thinking about and that's the world that exists underneath the soil surface. Now it's very easy to take this world for granted because normally we interact with soil as this flat 2 dimensional surface, as you can see over on the left. On the right even when there's relief, even when there's hills, which obviously require this 3rd dimension for coming up and down, our interaction with the soil is normally still very much 2 dimensional. So that belies the fact that there's a lot of life below ground because there's this whole world down there. In fact it may be surprising to some of you that there's actually more below ground biomass than you can see above ground in either of these places. Now these are not floodplains, I will get to those in just a second. So I'm just setting the scene for now just to give you an indication of just how much life there is down there.

So if you were to go into an average UK grassland, if you could somehow magically lift all of the microbial biomass that exists below ground up above the ground, you'd have this kind of quivering, massive jelly made up of bacterial cells, protozoa, fungal hyphae. If you could do that, you’d see an equivalent biomass to about 2000 sheep per hectare. Now I suspect 2000 sheep per hectare isn't a unit that means a lot to many of you because these days people are much more used to working in units such as blue whales or double decker buses. So to give you some context for that the maximum stocking density that's allowed for sheep within the UK is just 12 sheep per hectare. So that gives you an indication of just how much life there is that exists below ground.

So that was in grasslands in general, how does that compare to floodplain meadows? Well in floodplain meadows you could have even higher levels of life and that's because due to these periodic inundations that happen when these areas flood, they bring in this river water which contains large amounts of dissolved organic carbon and other nutrients. As that water percolates down through the soil, it takes this substrate, this food source down which the microbes can use. In normal grasslands it's just rainfall that falls on the surface so they only get carbon inputs from the plants that are there, either from exudates or from leaf litter this time of year.

So this means rather than just finding life near the surface, in your average grassland soil you'd find most of your life in the topsoil, the top 10 to 15cms, and whilst you can find life as a decreasing gradient all the way down to the bedrock, and indeed even within the cracks of the bedrock, it tails off quite rapidly once you get down into the subsoils. That's not the case to the same extent within floodplains. Within floodplains we have relatively large amounts of biomass, even down to depths of as much as 3m. Now you can see in this figure which is taken from the paper that I leaned to, generally we have different microbial communities in the surface to the subsurface. For the ecologists in the room, the surface bacterial communities are generally r-strategist and down at the bottom they're more k-strategist. So what does that mean? Well, if you look at the activity of these microbes, that you get more activity in the surface communities, they are exposed to more environmental change up there so they need to be able to adapt to that. When you get down to the microbial communities which are much deeper, they are not so prone to these rapid changes that you see near the surface. Actually they have much higher levels of carbon-use efficiency. So for every unit of carbon that makes it down to these deeper levels these microbes are much better at integrating that carbon into the biomass than those at the surface who generally respire their carbon and emit it back to the environment as carbon dioxide and use it for energy rather than growth.

Now we've seen a soil profile that was just dug up with a soil auger. I suspect some of you may have seen soil profiles like this. So I mentioned earlier, we normally deal with soils as this 2 dimensional flat surface. Indeed even when we dig down into soils, which obviously requires that 3rd dimension of depth, we still see this flat 2 dimensional structure of either a normal grassland soil that you can see on the left here, or in a floodplain grassland that you can see on the right. That belies the fact that there's this complicated 3 dimensional environment.

Without realising that, it's fairly easy to ask the question – where is the life? How can there be so much life within this soil, more than 2000 sheep per hectare equivalent in your average floodplain meadow. But where is it? Well it's all about scale. So again, we normally walk around on soils that are about this sort of scale, somewhere between 5 and 6 feet, your average person above the soil. Sorry for using the imperial measurements. As we zoom down into the soil you start to be able to see some of the texture that exists within the soil. This is what you would see if you moved down and looked closely at a soil pit. Now if you move and look through a microscope instead you'd start to see there's space within the soil. These are plant roots which are growing down through the soil profile. You can see at the top and the bottom, there's quite a lot of space there. That's the space where life makes its home. But to really appreciate it you need to look through a compound microscope. Now this is a thin section of soil. Soil has basically been embedded in resin and then thin slices were taken through the soil which allows you to see images such as this. Within this image all of the dark colour that you can see is the soil mineral phrase, the solid fraction of soil. But all of that yellow that you can see is the pore space. An average soil, if there is such a thing, is about 50% pore space and only about 50% solid matter. But still this doesn't really give justice to the complexity of the system that exists at the scale of microbes because we're still interacting with it as this 2 dimensional flat surface.

So if this works I'm going to try and show you a video which is going to look like computer graphics. Indeed it is computer graphics, but it's certainly not a computer game. What this is, this is an x-ray tomograph of a soil sample. Basically a cubic millimetre was very carefully removed as an undisturbed sample and placed in this bit of equipment which basically fires x-rays at the soil sample, twists the soil sample round and fires more x-rays and does that repeatedly, and then uses all of those images to reconstruct a video. So if you could shrink yourself down to about the size of an amoeba, this is what the soil looks like to you. So it’s this 3D labyrinth of large pores, small pores, some of these pores will be filled with water, some of them will be dry, depending on the last period of inundation, or the last period of flooding and actually this doesn't do complete justice. There's a limit of resolution to this system. So actually on the walls of this there will be pores within pores and everything gets a bit fractal, but that's a presentation for a different day.

In case you have any difficulty in still picturing what an amoeba looks like within a soil pool, well this is what they look, like this is an amoeba. They don't actually glow like this. This is a type of epifluorescent microscopy. But these organisms are very well adapted to the soil environment. They are little bags of jelly that can squeeze through these tight pore spaces. They do that because basically they feed on bacteria. Here again, these are stained bacteria, bacteria don't glow either. But you can see these blue dots, they are stained bacteria, and they preferentially grow on the pore spaces of these soils. So there's a pore here and a pore here as you can see, and this is the solid phase. These are the bacteria that I'm talking about. Now that's quite a good place for bacteria to live because as the water percolates down through it brings them their food source, dissolved organic carbon, but it also takes their waste away, any of the waste that they produce. Now the downside of being here is any protozoa that are crawling around through those pore spaces can graze on those bacteria. Bacteria don't have legs, they can't get up and run away. Then we sometimes end up with other situations where bacteria can be growing within aggregates themselves. Now it doesn't look like it but soils are actually quite dynamic environments. Aggregates are breaking apart and reforming under various processes such as wetting and drying and freezing and thawing, so you can end up with bacteria completely encased within aggregates. Now this is quite good. They're protected from protozoa but they're dependent on the rate of diffusion to bring their food in, and indeed, the rate of diffusion to take their waste out. If it so happens that the food is coming in quicker than their waste is leaving them well these bacteria will end up killing themselves in their own waste, which is never a nice way to go.

So it's not just bacteria that can end up trapped within these soil aggregates. Soil carbon can as well. So this is one of the reasons why grasslands are very large carbon stores. As these aggregates form they can sometimes form around old plant roots, for example, and that carbon becomes protected. These bacteria would love to get in there and eat it to decompose it or mineralise this soil organic matter but all the time it's completely encased in soil, they can't. When you have a period of inundation that can cause a process called slacking, basically air pockets within the soil getting under increasing pressure and that can split these aggregates open. When that happens that can release the carbon and allow bacteria to get in there and break down that carbon. Depending on the environment that they're in, that carbon will either be released as carbon dioxide if they're respiring aerobically, or potentially as methane if they're respiring anaerobically. So this is a key factor and a key function of soils in floodplains. There are many, but with only a 10 minute presentation, I'm only going to talk about 2. One of them is these soils don’t just store carbon, they also interact with greenhouse gases in the atmosphere by either producing them or breaking them down. Now I mentioned just now these can produce methane under anaerobic conditions, whether that methane actually makes it all the way up through the soil profile and into the atmosphere to exacerbate climate change, that depends on how high the water table is. That's because basically depending on the level of water you will quite often have an aerobic layer at the top and an anaerobic layer at the bottom. When these soils are inundated, the groundwater rises up and you can end up with a very thin or a completely absent aerobic layer. In those cases any of the methane that's produced will generally bubble up through into the atmosphere. When these soils dry out a bit we would normally have a lot thicker aerobic layer near the soil surface and there's a group of organisms called methanotrophs which are actually capable of using methane as a substrate. They can use it as their food source, as their energy source. So if that's the case and you have this large aerobic layer, because it's been a while since the previous inundation, well then a lot of that methane as it gets bubbled up will actually get oxidised by these methanotrophs and turned into carbon dioxide. So just because methane is produced within these soils, it doesn't mean they are sources of methane. Sometimes they can still be sinks of methane as most aerobic grasslands are.

Now this isn't just the case for carbon. There's also a very important nitrogen story. I'm sure many of you are aware that nitrogen cycling requires both aerobic and anaerobic processes. Again, the proportion of this that is being favoured will be dependent on how high the groundwater is. One of the key consequences of this denitrification pathway is the anaerobic pathway and this can involve N_2O production which is a very powerful greenhouse gas, it can be almost 300 times as potent CO_2. So once again as the groundwater rises we'll have an increase in the amount of N_2O that's being produced. Most of the time, there are obviously exceptions to this, but other times when we have a large aerobic layer at the top, there's a good chance that that N_2O will be completely oxidised or reduced through the nitrogen cycling.

So that's just a very brief introduction to microbes below ground and what it is that they do within floodplains. Now my marketing department wouldn't be happy with me at all if I didn't share a nice picture of our university as the final slide. So with that I will thank you for your attention.

Sue: Thank you very, very much. That was so fascinating and I really appreciated the graphics, particularly the amoeba tunnelling through. I thought that was fantastic. I've learned so much from that one and I suspect there's going to be some questions from all 3 of those talks. I think that we’ve got a few in the chat which I can address straight away. One of them is a question to your good self and I just wondered if the paper you referred to, you might be able to put a link to it in the chat so people can see that.

Simon: Yes absolutely. I'll do that.

Questions Session 1

Kevan: So you had the example of 2000 sheep. That's a lot of sheep producing a lot of CO2. So I wonder we've been talking about carbon capture, but obviously your soils are releasing vast amounts of carbon dioxide, if not also methane and I just wonder when you look at the balance what is the balance of capture versus release in these species-rich soils?

Simon: That's a very good question and the answer is, well it's the classic scientific answer really, the answer is it depends. It depends on a lot of things. During the winter when it's cold generally there will be less carbon being emitted from these soils. When you've just had a period of inundation that will generally increase the amount of carbon that's being emitted in either carbon dioxide or methane and actually it’s one of the big pressing questions in soil ecology. There's a very famous paper that came out in 2006 called The Soil Carbon Dilemma. One of the things that we have to appreciate with carbon in soils is the dilemma exists because we want carbon to be stored within soils because that helps mitigate climate change and indeed the government is planning on trying to pay farmers to store more carbon in their soils. But actually all of the life that's within soils does very useful stuff for us. It provides numerous ecosystem services and the only way that they can do that is by respiring carbon. They need to do that, they need to access the soil organic matter and burn that off as carbon dioxide in order to do the processes that we refer to as ecosystem services. So it's a complicated question and the best answer I can give really is it depends. Most carbons are slightly carbon sinks but if you, for example, drain peat-heavy soil, it becomes very much a carbon source.

Wolfgang: Just a question about the correlation between biodiversity and carbon storage. How is the correlation, which way around? Can I increase biodiversity and that increases the carbon storage in floodplain meadows, or is it only good soil in a floodplain meadow that generates a good species-rich grassland?

Simon: So, in general, if you increase the amount of plant diversity you've got which will increase the rooting depths of those plants, which means there will be root exudates being put out through the soil at different depths which will stimulate more microbial growth. As those microbes grow and you have more microbial biomass that is a form of carbon being stored within the soils. So in general, yes, if you have more biodiversity within a floodplain meadow, you would expect there to be more carbon storage mainly because of their rooting profiles. Now that is true within floodplain meadows but how much you can extrapolate that out. There is actually a bit of a disconnect once you get up to the global scale between above ground and below ground biodiversity. For example, where everybody knows the most biodiverse areas are our rainforests, for example. But actually below ground biodiversity in those areas is relatively impoverished compared to temperate grasslands, for example. So within floodplain meadows I would say yes. Increasing diversity most likely increases soil carbon.

Wolfgang: So it's this way around, so I can improve biodiversity and that improves the carbon storage or is it the other way around that on a good floodplain meadow soil wise, I will have a species-rich grassland and by just adding some more species to the grassland it wouldn't change the soil really?

Simon: It depends, it’s all down to the plant traits really. So if you add more species that have very similar traits, then you're probably not going to have much of a difference. If you're increasing biodiversity and you're changing the profile of the roots because some have deep rooting traits, some have shallow rooting traits and so on, that's what would maximise carbon storage.

David: I think Simon's already mentioned the point that there is evidence to show that species-rich plant community does correlate with higher soil carbon for the reasons he mentioned. The more diversity in rooting structures and rooting depths allows the community to utilise the soil more fully for more of that root exudate to be deposited in the soil and be processed by the microbial community. So yes I think where there is a correlation it's a positive one. The more diversity you have, the more soil carbon you have.

Emma: Are there any more questions? I can pull one out from the chat as a follow up from Dan who asks - Does the amount of carbon stored in grasslands reach a point of equilibrium or does it continue to sequester carbon indefinitely? If we’re restoring ex-arable land when is the fastest period of sequestration likely to take place?

Clare: I would say it seems to be just from the data that we've got that it's quite rapid after converting from arable to grassland with diversifying of the grassland seed mix. So that seems to be quite rapid. But I think David's already pointed out that these floodplain soils, they accrete so we've got sediments depositing on and so the soils are actually growing deeper and therefore within that profile just by that they are increasing.

Simon: I would just say all mineral soils that are aerobic basically can saturate with soil, there's only a finite amount that you can get in there which is dependent, a lot to do with texture but also to do with other environmental properties. The only way you can get beyond that is if you have a continuously flooded area which over time turns into a peat bog or something like that. That will be the only way you could add more.

Emma: I'm going to ask one more from the chat – How can compaction in clay soils be detected, from Ann Cantrell.

David: As I mentioned in the video it's difficult to do it using an auger because you are disturbing the structure as you take the soil samples out. So really to do it properly you need to dig a soil pit and then you can see. Horizontal striations is the tell-tale sign of compaction, particularly from vehicles. But it's an issue within protected species-rich sites that you don't want to be digging large soil pits. So there are other methods such as penetrometers that push a needle into the ground and you measure the force required which can be useful if you can calibrate it for your particular soil type and so that method is used. But a soil pit is really the best way but it is a rather high disturbance method for looking at compaction.

Martin: I have a question to the speakers similar to the question that Ed has put in the chat. So where floodplain meadows have previously been drained, so the water table has been reduced because there's perhaps been dredging, if you reconnect the river to the meadow, what are the implications in terms of, obviously you're increasing inundation but also you might be increasing the water table. So are there particular issues when you've had the water table become quite low because of the disconnect and now it's raised back up again.

David: So Martin's talking about reconnecting the floodplain to the river after a period of drainage. So it may have spent years with artificially low water tables due to a drainage system. I don't think there have been many studies on that sort of hydrological restoration scenario so it would be difficult to point at any numbers. But my expectation would be by making the soil wetter the carbon potential to store would increase but only to a certain point. When the water table becomes very high, and I answered somebody's point in the chat about when a grassland is regularly inundated and is anoxic most of the time, then the carbon tends to be restricted to the surface soil because the plants tend not to root deeply. If the soil is permanently anoxic few plants will push their roots down into it, so you tend to get concentrated carbon at the surface but less at depth. So the total carbon would probably not be as great. So I think with many of these things it's a matter of balance so having a water regime that's slightly intermediate the soil is kept moist but not anoxic will maximise the amount of carbon. So reconnecting previously drained floodplains is probably a positive thing but not impounding water on them that creates permanently anoxic soil conditions is probably the best way forward.

Emma: We will try and carry on answering the questions that have come through in the chat. There's lots of questions actually so we don't have time to ask more now to the panel but hopefully the panel will be around for a bit longer to answer questions. I know David is responsible for monitoring the chat this morning as well. So hopefully you'll get some other answers. I'm going to wrap up now and hope that Sue can re-join us in 5 minutes time where we'll start again at 10.30. So it's just a chance for a quick break. Thank you all.