

## Enriching soil with biochar

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Adding charcoal to soil regularly over a long period has been shown to radically improve soil and its ability to support crops. Organic carbon in soils is lost as forests are replaced by crops. Gradually over time, the soils decline. Adding biochar is a remedy. It's a method that has been employed by some Aboriginal and South American cultures for centuries. In South America people created charcoal and added it to soil, deliberately, knowing that it enriched soil. The NSW Department of Primary Industry is running biochar experiments in a range of locations. Jos Webber runs a coffee plantation on the north coast hinterland of NSW and shows Robyn Williams his biochar experimental plots. Some field trials show significant sequestration of carbon dioxide. Lukas Van Zwieten and Stephen Kimber describe changes in soil chemistry when biochar is added.

### Transcript

**Robyn Williams:** Now, as you know, the answer lies in the soil.

Lukas, what are we looking at?

**Lukas Van Zwieten:** Simply here we have got a control site where there has been no biochar applied, and in the next row across we can see here these particular coffee plants have had poultry-litter biochar applied in a band, covered in mulch. What I'm about to show you is some of the biochar left in the soil and some of the effects you can see here are much healthier-looking plants. Certainly the total biomass appears to be higher, and it's part of what we are currently measuring in these trials. But I'll show you what the biochar looks like in soil.

**Robyn Williams:** And I can see the berries all over the place. Right, that's underneath...

**Lukas Van Zwieten:** So here, Robyn, we can see that the biochar has incorporated beautifully with the soil, we can see lots of root material in the biochar soil layer, and I just saw a little earthworm slithering away. So it's very, very clear that this poultry-litter biochar has incorporated beautifully in the soil, and I think some of the soil chemistry results will show that we are getting improvements in a number of the soil functions like nutrient holding capacity and probably available phosphorus in the soil.

**Robyn Williams:** It's amazing that it has that sort of effect, as if it was there in the first place and it has sort of gone missing and somehow the soil is depleted of what it was used to.

**Lukas Van Zwieten:** Certainly most of the ferrosols or the krasnozems up in the north coast were once part of the big scrub rainforest, and when these soils were converted into agricultural soils there was a decline in soil organic carbon, and what we are simply doing here is replacing some of that carbon in the soil through applying biochar. And we are seeing the benefit that I guess the early pioneers saw from these soils, which were extremely fertile soils.

**Robyn Williams:** Yes, the brown stuff, red stuff, and mixed with the black stuff, it looks almost good enough to eat.

**Jos Webber:** If you were an earthworm, yes.

**Robyn Williams:** Thanks Jos, that sums it up.

Me on a coffee farm in northern New South Wales with some biochar scientists you are about to meet, like Lukas Van Zwieten at the Department of Primary Industry laboratory in Wollongbar, New South Wales.

Give me some of the history of biochar. Some people suggest that it's pioneered in South America and to some extent England, is that right?

**Lukas Van Zwieten:** Certainly the terra preta soils, which are the dark earth soils of the Amazon, has also been found in the plaggen soils in the UK, but I guess more recently Adriana Downie from the University of New South Wales and our group here at Wollongbar have been working on the terra preta Australis soils, so soils that have been developed by Aboriginal midden sites along the Murray River.

**Robyn Williams:** And this is biochar in the same kind of tradition of pyrolysis, making charcoally stuff and putting it in the soil.

**Lukas Van Zwieten:** Yes, very similar types of technologies. Obviously in modern times we've got more engineered processes. You know, 2,000 years ago when these terra preta soils were developed, there were more rudimentary kilns or even earthen cooking fires where similar processes happened where you get carbonisation of biomass and a charcoal type material forms.

**Robyn Williams:** Where do you find these ancient sites?

**Lukas Van Zwieten:** Certainly along areas of population. So in the Amazon region, for example, there were civilisations, so the pre-Columbian civilisations had maybe 100,000 people and they formed pottery kilns where then the charcoal was put onto the agricultural land. In Australia the terra preta soils occurred along the Murray River where again the populations had their cooking fires and the earthen ovens, and then those charcoals were then applied to the soil around their camps.

**Robyn Williams:** How do you know they were applied to the soil to grow things rather than just dumped out of the way?

**Lukas Van Zwieten:** Certainly in South America there is very strong evidence that the charcoal was applied for farming purposes because it was over larger areas, and some of the anthropological evidence is tending towards providing further information on those sites being used for agriculture. In Australia it was probably more of a situation of the charcoal being dumped, but we are learning lots of things about charcoal being applied in Australian soils.

**Robyn Williams:** So you're actually seeing signs that they may have been used to grow things back then.

**Lukas Van Zwieten:** Certainly in South America.

**Robyn Williams:** In Australia?

**Lukas Van Zwieten:** No, we don't believe that there was any evidence of Aboriginal midden sites being used to grow anything.

**Robyn Williams:** There just happened to be charcoal.

**Lukas Van Zwieten:** There just happened to be charcoal being applied in the soil, but what we are finding now is that these soils where the charcoal was applied are forming terra preta properties. So the soils are actually very similar in their chemical and physical properties compared to the soils in South America, I guess which gives us now the information to then start applying biochar into agricultural soils in Australia.

**Robyn Williams:** Tell me about the word 'terra preta'.

**Lukas Van Zwieten:** 'Dark earth', it translates directly to 'dark earth'. You can imagine a native soil without charcoal in it often being a washed-out red colour or a very pale colour, directly next to these fairly aged soils, say along the Murray River, you then have these very, very dark soils, often black in colour. They are far more friable, much lower bulk density, much higher carbon content, and all of the nutrient properties are far more amenable to growing good food crops.

**Robyn Williams:** What sort of experiments are you doing here at the institute?

**Lukas Van Zwieten:** We've been working on biochar at Wollongbar since 2004, and since then our department has ramped up its efforts. We've got field trials in the Northern Rivers of New South Wales, there are staff doing field trials in Tamworth, and we've also got field trials in Wagga. So there are certainly a large range of trials. We are testing different types of biochar in different soils under different farming systems, I guess trying to find out what works and why it works.

**Robyn Williams:** Dr Lukas Van Zwieten. So to make your carbon to put in the soil, you can cook but not burn almost any organic material. How do they make it there in the lab?

**Lukas Van Zwieten:** We use an engineered pyrolysis for preparing the biochar. We don't actually make it per se, we purchase it from companies in Australia. Australian companies actually make biochar often as a by-product from bioenergy production.

**Robyn Williams:** What out of?

**Lukas Van Zwieten:** Some of the feedstocks that we've tested include animal manures, we've tested council green waste, we've tested rice husk materials, we've tested a range of agricultural residues, some sugarcane residues, certainly a very, very wide range of feedstocks. So the biomass material is heated in the absence of oxygen and then the flame is external in the kiln, so during that heating process the biomass releases what is known as syngas or synthesis gas which is a mixture of methane, hydrogen, and carbon monoxide, which is a very high energy gas which can then be used either to fire the flame for the pyrolysis process, with surplus energy being used to make electricity, or for other heating purposes.

**Robyn Williams:** Could you show me some of your plots here?

**Lukas Van Zwieten:** Let's go down and have a look at some of the field sites.

**Robyn Williams:** And the first of those sites that Lukas wants to show me is back on that coffee farm. It is run by Jos Webber at Tintenbar, not far from Ballina, New South Wales.

**Jos Webber:** Well, we've had a very good season, plenty of rain, and as you can see everything is very lush and green.

**Robyn Williams:** Does coffee like rain?

**Jos Webber:** It loves the rain, loves the slightly cooler summer we've had, and yes, it has thrived through this season.

**Robyn Williams:** How long have you been growing coffee here?

**Jos Webber:** Eight years, so it's eight years since we've planted our original plantation, and then this younger plantation is just over two years old.

**Robyn Williams:** And where are you putting the biochar?

**Jos Webber:** We've got four different treatment groups within the plantation, and each of those has three replicates. And we've got two different types of biochar we're trialling, one is made from poultry litter and that's an Australian biochar, and the other one is made from rice hulls and that was imported from the Philippines.

**Robyn Williams:** What made you go into this experiment in the first place, Jos?

**Jos Webber:** I guess I am a microbiologist by training and I have an interest in soil health, and when I heard that the DPI was looking for somebody with a coffee plantation to do a trial on, I put my hand up and volunteered.

**Robyn Williams:** And Lucas came along and persuaded you.

**Jos Webber:** That's right, yes.

**Robyn Williams:** And so you've got four different schemes going, four different trials. Any results so far? Can you tell the difference between the plants growing?

**Jos Webber:** It's probably a little bit early. After the biochar had been on a year, it looked to us that there certainly was a bit of a difference. I measured the height of the trees after a year. There is one group that is untreated with no soil remediation at all, there is another group that has just got straight compost, a third group has compost with the rice biochar, and the fourth group has the poultry litter with compost. So we had to put the compost on to keep the biochar from blowing away. Ideally we should have put the biochar on before we planted, but things just didn't work out, so the next best thing is that we banded it along there and then covered it with the compost.

And after about a year, the ones that seemed to be doing the best were those that were treated with the poultry biochar and compost mixture. The ones that were doing least well in terms of their height were those without any treatment at all. So I guess in a way it is not only looking at the effects of biochar but it is also looking at the effects of just treating with compost and not treating with compost.

**Robyn Williams:** What sort of soils do you have here basically?

**Jos Webber:** These are krasnozem volcanic red soils, so it's very deep, very fertile soils.

**Robyn Williams:** And how much coffee would you produce here for an annual crop?

**Jos Webber:** Production in terms of green bean, each tree produces theoretically about a kilo, but in reality we only get about 400 to 500 kilos. So that's about 3,000 kilos per hectare.

**Robyn Williams:** Does Australia produce much coffee of its own?

**Jos Webber:** We import 92% of the coffee that is drunk here.

**Robyn Williams:** I thought so. It always struck me as quite weird that we import things like cashew nuts and coffee which we could so easily grow here as well.

**Jos Webber:** Yes, we've got a very good climate for coffee here, and it is also grown in Far North Queensland on the Atherton Tablelands. We would very much like to have more growers because there is a big demand for our product because I think more and more consumers are becoming conscious of eating Australian and drinking Australian.

**Robyn Williams:** And fair trade as well, all that sort of thing, it is a very political thing, coffee, isn't it.

**Jos Webber:** It is, yes, there is a whole political agenda, and everybody likes to have fair trade on it. But I reckon I'm fair trade too, with my own bare hands.

**Robyn Williams:** Jos Webber of Kahawa Coffee. And so back to Wollongbar and the DPI lab.

Right Lukas, we are out in your plot, introduce me to your friend.

**Lukas Van Zwieten:** With me we have got Stephen Kimber. Stephen is a research chemist with us here at Wollongbar, and his particular interest with these biochar trials is investigating the emissions of greenhouse gases from soil.

**Robyn Williams:** Stephen, it's raining of course, can't you stop it raining here ever?

**Stephen Kimber:** I've given up on stopping the rain here, Robyn, I'm afraid.

**Robyn Williams:** You got some dairy cows over there, are they dairy cows?

**Lukas Van Zwieten:** These are part of the beef breeding trial. That said, we are still doing research on dairy pastures, which is the plot that we see in front of you here.

**Robyn Williams:** What is here in front of us?

**Lukas Van Zwieten:** What you see here are three research trials. The first trial here has been established in 2006, and it is one of the world's oldest replicated field trials testing biochar. And we've got a range of different biochars to test how well the biochar interacts with the soil. I mentioned before that some of these plots are accumulating a significant amount of carbon in soil, in fact up to around 40 tonnes of CO<sub>2</sub> has been sequestered in some of these soils after we have added the biochar.

**Robyn Williams:** And what sort of effect has the biochar had long-term on the soil?

**Lukas Van Zwieten:** Certainly our available phosphorus has been significantly increased in these red soils, and these red soils are notorious for tying up phosphorus, so as soon as you apply superphosphate fertiliser you are starting to get that phosphorus binding to the clay minerals. With the biochar present we tend to have less of that occurring, and the plants are able to access the phosphorus in the soil for a much longer period of time.

**Robyn Williams:** Stephen, you measure the gases coming out, is that right?

**Stephen Kimber:** Yes, that's right, we are measuring the greenhouse gases, but in particular nitrous oxide we are interested with the influence of biochar, and we have seen evidence, particularly in the laboratory, of reductions in the generation of nitrous oxide with certain biochars, and we are extending that work into the field so we can prove that it's a real effect.

**Robyn Williams:** But here you have got an open field, you've got some apparatus in front of us down by some mobile lab, I suppose it is. Is that how you measure?

**Stephen Kimber:** Yes, we have got some closed chambers of about one square metre that come along with this, they are out of the field at the moment following the harvest, but they are opened and closed automatically so that emissions can be measured on a continuous basis across 12 different plots so that we can get the replication we need to prove what we are after, and we can get a very good cover over time.

**Robyn Williams:** Were you surprised by the result you are getting so far?

**Stephen Kimber:** No, look, the chemistry of the biochar suggests that you are going to get a reduction in nitrous oxide. We have studied that in theory, we've extended that to the laboratory and we have proven that occurs with certain biochars, and now we are getting the first data from this in-field greenhouse gas apparatus and we are just in the midst of analysing that data currently.

**Robyn Williams:** Do you know what's going on down there? Is in fact the nitrogen being tied up by the various bugs and growth and so forth?

**Stephen Kimber:** That would appear to be possibly the main mechanism. There are some other minor mechanisms of catalysis and a few other chemical processes that can be happening.

**Robyn Williams:** Lucas, let's get down to earth on this, so to speak. When you put the biochar in, the extra carbon in, you would expect it to have a fertilising, boosting effect, but it does far more than that, doesn't it, it actually affects the micro-organisms in the soil. How?

**Lukas Van Zwieten:** Certainly there is evidence now showing that biochar can influence a range of soil health parameters, including soil micro-organisms, and there are various groups around the world doing work on impacts of biochar on, for example, nitrogen fixation. We've got some very good trials here. In fact the trial you see at the bottom of the plot there with legumes is showing that we are getting significantly improved nitrogen fixation in the presence of biochar derived from poultry litter.

So there certainly are a range of mechanisms, it is not just simply a fertilisation effect. We are getting interactions with the clay minerals, we are getting improvements in cation exchange capacity, we're getting improvements in soil physical characteristics like aeration and water-holding capacity. We are just trying to understand now what the actual mechanisms are. We do know that certainly in the red soils that are acidic we are getting some very good responses, but we have also done trials in some soils where we are getting far less of a response. So we are just trying to now understand what the mechanisms are and try to optimise any of the benefits.

**Robyn Williams:** And it's not as if the carbon is just being used up and depleted as you watch these crops grow, is it, they are somehow being solidified, the carbons.

**Lukas Van Zwieten:** Certainly the biochar carbon is a very stable carbon, and in fact one of our colleagues, Dr BP Singh, is doing some pretty clever work on estimating the longevity of these biochars in soil, and his trials are showing that these biochars should last between 100 to 1,500 years in the soil, and it's not just then the particular biochar that's in the soil, it's the impact of how these chars interact with the labile or the native soil carbon. That I guess is the area that we are really starting to research now and we are particularly excited about.

**Robyn Williams:** Well, do you share that excitement then, Stephen?

**Stephen Kimber:** I certainly do. We've seen in one particular biochar here in the pasture plot, we've seen a definite stabilisation of the native soil carbon over and above what is happening in the controlled plots and even in some of the other biochar plots. And we're using various techniques to try and work out exactly why that carbon is being stabilised and why we are getting the build-up over and above the carbon we are already storing via biochar.

**Robyn Williams:** But your biochar has got to be made presumably. Do you think, in your wildest dreams, you can get it on a scale that could somehow change Australian agriculture?

**Stephen Kimber:** Look, we are certainly hoping for that. I think we have got to take small steps to begin with. We're trying to get our first plant established, we have interest in our local council, they are certainly taking the right moves towards assessing the feasibility of the project. We have got a lot of degraded land in Australia and we are not going to have vast amounts of biochar for some time, but I believe that definitely we'll be seeing some changes into the future.

**Robyn Williams:** Lukas, have you discussed that question; where will all the biochar come from that will be on a scale to make this really a big difference?

**Lukas Van Zwieten:** I guess one of the advantages of biochar and the pyrolysis process is that we can use much lower-value biomass materials. So biomasses that would have otherwise gone into landfill can actually make some very, very high-value biochars. And we are working now with some of the Australian owned companies that are developing these biochar technologies and working with them, trying to work out what biomass residues we can actually use to make both bioenergy in the form of electricity, and biochar.

**Robyn Williams:** So the electricity, as you said before, would come from the actual slow pyrolysis of this material, and then you've got the product at the other end. Has anyone worked out actually how much you would need in terms of this biochar material to get things going in about ten years time?

**Lukas Van Zwieten:** I think that's a really good question. My crystal ball is a little bit hazy on that particular topic. I think that, as Stephen mentioned before, we are going to have slow development of the technology. There are already a couple of companies now starting to put in smaller units. We need to demonstrate that these units can be economically viable, that's going to be the critical first step. We've got people in Australia doing work on life-cycle assessment, and that is something that is very important as well, we need to demonstrate that this particular technology is better than burning the biomass in a coal-fired power station or better than landfilling. So we need to actually get hard data proving that this technology works well. And we are well and truly on the way to developing some of these life-cycle assessments for the biochar technology.

**Robyn Williams:** Before we get the rain pouring down again, Stephen, crystal balls, I'm sure you've thought about this, what are your wildest dreams?

**Stephen Kimber:** What we're going to see are small plants scattered around the countryside, like the local council site we've got hopefully coming up here, sugar mills where you've got large supplies of biomass can transfer over to the biochar technology. So you are going to see these smaller plants scattered around the place, they are going to be harvesting biomass from a small area, and the biochar will be used within that area so that you don't blow your greenhouse gas benefits by the transport using fossil fuels.

**Robyn Williams:** But many, many tonnes of carbon being sequestered in the process per acre. It's quite surprising how much you do get in for a small plot of land, isn't it.

**Stephen Kimber:** It is, and we've got research that suggests the sort of levels of carbon we want to put in to get an economic return. But I think we are not worried about the upper level of soil carbon at the moment because certainly the supply is not there. I think we are a long way off from worrying about putting too much carbon in the soil.

**Robyn Williams:** Steve Kimber and Lukas Van Zwieten at the DPI lab and field site at Wollongbar, New South Wales. And some final thoughts from one of those on the receiving end of all this effort to enrich the soil and sequester carbon, farmer Jos Webber.

Is there any way that you could make your own biochar rather than, as most people, Lucas was saying, buying it from manufacturers?

**Jos Webber:** I've not really looked into the small-scale production of biochar. We do have quite a lot of prunings from the plantation, and also from the surrounding rainforest which I guess could go into biochar. Also the other product which we currently don't have a good use for is when we process the coffee after

harvesting, the pulp that is taken off is very high in sugars and very fermentable, and so that probably has a use which we haven't fully explored yet.

**Robyn Williams:** I must say they look thriving, these plants, they are something like a metre and a bit tall and lovely rich, green leaves. When do they actually produce the fruit?

**Jos Webber:** We normally harvest from about October through to early December. It flowers in about September/October, so yes, it takes about a year from flowering to maturity and when we harvest the ripe cherries.

**Robyn Williams:** One thing about the Northern Rivers area and southern Queensland, it is so very much subtropical, tropical, you've got any number of insects. Any pests that you have to worry about?

**Jos Webber:** We are unique in that we have no pests or fungal diseases that affect our coffee...

**Robyn Williams:** Isn't that brilliant!

**Jos Webber:** We have no need to use fungicides or pesticides on our coffee.

**Robyn Williams:** How astounding.

**Jos Webber:** And that is really something we want to fiercely protect. Hawaii is the other place that has a similar sort of climate and lack of pest problems but until just very recently, and they have now got one of the major coffee diseases in Hawaii and that came as a result of imported raw coffee into Hawaii. So that is something we really need to be very aware of and we will be talking to the quarantine people about it, just to make sure that we have measures in place that will prevent that.

**Robyn Williams:** Just finally on the biochar side, any problems getting enough supply that you need, despite the fact that you've got a good relationship with the institute and they can supply some? But if you were an independent grower, would there be a premium?

**Jos Webber:** I think it would be at this stage not economical to apply it, it's just so expensive and very difficult to get. So it is very much I think still in the experimental stage. And we're hoping that this trial and others around will convince people that there is a commercial value and if it could be produced in the right volume it can be utilised, because it is a one-off treatment and that's the beauty of it.

**Robyn Williams:** I see, you put it in once and there you are, set.

**Jos Webber:** Once it is there for, Lukas says, 5,000 years.

**Robyn Williams:** Which is as long as you will be growing your coffee.

**Jos Webber:** Absolutely.

**Robyn Williams:** Any other farmers interested?

**Jos Webber:** Yes, we had a number of field days here and we get quite a few visitors and everybody is very interested in the biochar, and they've heard about it but not really understood what it is. So it's a good opportunity to showcase that.

**Robyn Williams:** Keen farmers in northern New South Wales. I was with Jos Webber at the Kahawa estate near Ballina, and his coffee tasted very good indeed.

**Music:** Excerpt from Bach's Coffee Cantata

4. Aria - Soprano

Ei! wie schmeckt der Coffee süße,  
Lieblicher als tausend Küsse,  
Milder als Muskatwein.  
Coffee, Coffee muß ich haben,  
Und wenn jemand mich will laben,  
Ach, so schenkt mir Coffee ein!

*Mm! how sweet the coffee tastes,  
more delicious than a thousand kisses,  
mellower than muscatel wine.  
Coffee, coffee I must have,  
and if someone wishes to give me a treat,  
ah, then pour me out some coffee!*

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## **Guests**

### **Lukas Van Zwieten**

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