Positioning biochar for a solid future

Dr Franco Miglietta has been developing biochar to sustainably sequester atmospheric carbon dioxide. He talks about the potential for its adoption through opening access to voluntary carbon credit mechanisms

What stage is EuroChar at in its assessment of biochar as a means to effectively sequester carbon while simultaneously improving agricultural soils? What have you discovered to date?

We are discovering many new things all the time. For instance, we have been able to estimate the fraction of carbon which is rapidly attacked by soil microbes in the field by using Cavity ring-down spectroscopy of the natural abundances of ^{13}C and ^{12}C in soil-respired carbon dioxide. We were able to gather this new data by using the peculiar isotopic signature of biochar produced from plants with C^4 metabolism – basically corn residues – which have been used by Advanced Gasification Technology and Carbon Solutions to produce biochar. We are also discovering that charcoal is favourably modifying soil properties over centennial time scales. For this, EuroChar is undertaking unprecedented research in alpine charcoal pits that were operated until the end of the 18th Century. Using molecular approaches in a model plant, we have also investigated detailed plant responses to the addition of biochar to the soil. This was carried out to elucidate a series of mechanisms leading to substantial positive effects of biochar on early plant growth.

Can you briefly outline the benefits of biochar?

Biochar has only been recently proposed as one of the most promising strategies to sustainably sequester atmospheric CO_2 in agricultural soils. Mitigation potentials of biochar were estimated to be as high as 12 per cent of current anthropogenic carbon dioxide emissions by Woolf and colleagues in 2010. This is something that might possibly be achieved under a win-win framework leading to a substantial enhancement of soil fertility, increased crop yields and renewable energy production. The long-term stability of the carbon contained in biochar was demonstrated to be greater compared to non-pyrolysed organic matter that was incorporated into soils with the same environmental conditions by a number of scientists from 2002-08. Biochar has an approximate mean residence time in the soil more than 1,000 years and this long-

term stability is a fundamental prerequisite to consider biochar as a suitable method for carbon sequestration. However, such an optimistic scenario requires more detailed and reliable assessment of direct biochar effects on crops and the environment, as well as an evaluation of socioeconomic implications. Most of the agronomic studies on biochar application were made in tropical and sub-tropical climates. In the meantime there is a significant lack of studies at mid-latitudes and in temperate climates.

By what means is biochar produced? How can approaches to its production differ?

Biochar is a carbonaceous residue of thermochemical transformation of biomass which occurs in the absence of oxygen. EuroChar considers two main types of biochar produced from gasification and hydrothermal conversion. Gasification is a thermochemical conversion process in which biomass is partially oxidised by heating at high temperatures to greater than 1,000 °C leading to the production of a gas mixture and a solid carbonaceous sub-product: charcoal. The primary product that results from this method is a gas produced during biomass gasification; this is conventionally called syngas and is a mixture of carbon monoxide and dioxide, hydrogen, methane and nitrogen. Gasification can be applied to a large range of products that have useful energy content.

Many different designs of gasifiers have been described in a range of literature, generally classified according to the characteristics of the bed of fuel and the way air or oxygen is introduced into it. Fixed bed gasifiers are distinguished in three main types: updraft, downdraft and crossdraft. In an updraft gasifier, air passes through the biomass from the bottom and the combustible gases are expelled from the top. The fuel essentially moves in counter current to the gas flow. In downdraft gasifiers, the air passes instead through the biomass in the downdraft direction and the combustible gases come out from the bottom. Here the fuel and air move in the same direction, with the main advantage being the production of gas with low tar content but high amounts of ash and dust particles in the gas. Crossdraft gasifiers are produced when the reactor operates at very high temperatures – around 1,500 °C and higher – with minimal tar-converting capability.

In a different process altogether, fluidised bed gasifiers are produced which instead are designed for large-scale applications, using smaller particle feedstock size and a bed of inert particulate material (sand) to form a turbulent mixture of gas and solid. Antal and Grønli found in 2003 that the production of charcoal may be substantial, especially in downdraft gasifiers. The resulting sub-product is normally a fine-grained, highly porous material that may significantly vary in its chemical and physical properties depending on the process parameters.

What aspects of the agricultural system are you analysing and by what means are you achieving this?

One of the key areas that we are working on is the testing of biochar effects on soils and crops with a particular focus on any resulting safety issues. EuroChar intends to answer three basic questions. Firstly, we are concerned with whether the production and field application of biochar is dangerous at all or if it can result in potential harm to human and animal health as well as ecosystems. Secondly, we are looking at how effective the carbon sequestration obtained using biochar is. In this case we are particularly keen to understand what the fraction of carbon contained in biochar is which actually remains in the soil over the long term. Finally, our consortium is interested in understanding more about the significant applications of biochar with regards to soil and whether this creates any problems or negatively affects the productivity of crops, grasses or tree plantations. To answer these questions we have prepared a specific work package which is devoted to biochar Life Cycle Assessment, where we hope that we can better assess the overall mitigation potential of biochar.

Is the production of biochar a carbon neutral process? Do you believe the costs outweigh the benefits?

The biochar option can be normally defined as 'carbon negative'. The carbon contained in biochar was previously contained in the atmosphere and when biochar is buried into the soil, a fraction of carbon dioxide is removed from the atmosphere. The Life Cycle Assessment studies that we are working on under EuroChar confirm that the production and agricultural utilisation of biochar have a large carbon-sequestration potential. We have a joint paper undergoing peer review that provides novel data on the whole gasification-energy production-biochar application chain specifically for rice.

What is the general opinion on biochar from the farming community and industry?

Very few farmers are aware of the possibility of using biochar as an alternative in their fields. Their interest could dramatically increase if biochar addition will finally open their access to voluntary carbon credit mechanisms. A farmer producing large amounts of useless crop residues may well be attracted by the idea of using gasification technologies or hydrothermal carbonisation (HTC) to transform biomass into recalcitrant carbon forms and then sell the carbon credits. The CarboMark platform, which is a voluntary Carbon Credit system that is now operating in Italy, has already introduced biochar in its schemes and we are looking forward to a rapid growth of biochar use. Several firms are already producing biochar in Europe, more frequently as a byproduct of energy production from biomass. They all see a potential for the biochar market and are anxious to see and evaluate EuroChar results, to create a market for their byproduct. Overall, the industrial and agricultural systems are ready to adopt biochar as a real solution. But more scientific data is required before progressing to implementation. Any regulatory policy, which is required for real-scale implementation, must be based on robust experimentation and solid evidence.

In your opinion, what are the next steps for advancing biochar's acceptance and adoption?

Factual interactions between the scientists and the media have been very positive so far. There is the need to communicate the results of scientific investigations to a much wider audience including policy makers. The media offers great potential in this area, provided that a proper bilateral and careful information exchange occurs between scientists and journalists. This is the next stage upon which to focus our efforts.

The power of collaboration

The **EuroChar** alliance is helping to develop biochar technologies in preparation for long-term carbon sequestration. The secret to their success lies in fostering effective teamwork and partnerships across Europe

AS INCREASING CARBON levels in the Earth's atmosphere begin to affect our lives, research efforts around the world are focusing on ways to transfer this carbon into valuable carbon deposits. These efforts are searching for effective strategies to reduce the impacts of greenhouse gas emissions by sequestering carbon in biomass or non-atmospheric carbon pools. One area receiving particular attention is the use of sequestered carbon to create beneficial products; for example, through the reforestation and afforestation of forest areas. A solution that seems increasingly likely to deliver a simple and effective answer to this problem is to enrich agricultural soils with carbon. However, there are some potentially negative effects that result from this, including the potential it has to increase other greenhouse gas emissions, the need for effective agricultural management practices to support carbon collection in the soil and the generally poor capacity of soil to actually store carbon.

An EU Commission-Funded Seventh Framework (FP7) Project is currently looking at ways to overcome these obstacles by investigating the potential of biochar – a carbonaceous residue of the thermochemical transformation of biomass – as a carbon accumulator which can be added to soil. The EuroChar project is looking at the two main types of biochar which are produced from gasification and hydrothermal conversion. Aerobic digestion leads to residues which are poor in carbon, whereas biochar is a carbon-rich product. This means that biochar differs significantly from the biomass which is produced through anaerobic digestion and is therefore believed to be highly effective at improving soil quality and carbon sequestration. The vision behind the EuroChar project is to form a multidisciplinary alliance that draws on the expertise of a number of European academic institutions, research centres and two Small and Medium Enterprises (SMEs) who are all involved in the thermochemical and hydrothermal transformation of biomass to help draw out the potential of biochar.

BUILDING RESEARCH LINKS

One of the key people in charge of this project is Dr Franco Miglietta, who is based at the Consiglio Nazionale delle Ricerche, Istituto di Biometeorologia in Italy. Miglietta is working alongside colleagues from a number of different countries including Italy, France, Germany and the UK. The two SMEs who are part of the EuroChar alliance – Advanced Gasification Technology and Carbon Solutions – specialise in both biomass gasification technologies which produce renewable energy and in biomass waste processing using a proprietary hydrothermal conversion reactor design. This means they can bring significant industry expertise to the project as well as provide opportunities for the research institutes to test their results on real-life scenarios. There are many benefits to be gained from working so collaboratively, including that a wide range of pressing problems can be responded to and investigated. "This kind of EU-funded research is highly relevant and very important, especially in areas where new knowledge is needed to urgently develop, and subsequently implement, new policies to help respond to rapidly evolving critical issues," highlights Miglietta.

Dissemination of results is an important part of the EuroChar project. The team is targeting both European and international groups, including policy makers, private companies, stakeholders and the research arena, as well as the general public. Press conferences, writing summaries for policy makers, presentations at major international scientific meetings and a dedicated webpage are all important methods used for

communicating the findings. The collaboration has also been active in publishing papers on the outcomes of their work. In 2011 they published conclusions to some investigations into biochar as a strategy to sequester carbon and increase yield in durum wheat in the prestigious *European Journal of Agronomy*. This work highlighted that the application of biochar has positive effects on biomass production and yield, with no consequential differences observed in grain nitrogen content. In early 2012, a paper looking at the surface albedo variations on agricultural lands following biochar application was published in *Environmental Research Letters*. Their work showed that plots treated with biochar showed a significant decrease in surface albedo.

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REAL-WORLD APPLICATIONS FOR BIOCHAR

A project of this scale and complexity is not without its challenges. One that is of concern to the EuroChar team presently is the effect biochar has on toxicity levels and its potential polycyclic aromatic hydrocarbons (PAH) content. Miglietta explains that biochar does contain PAH as does humus, peat and many other substrates. To address these concerns the team is now working on assessing the fraction of PAH that are contained in different thermochemical biochar production (TC) and hydrothermal biochar production (HTC) systems and to investigate just how strongly they are included in the biochar matrix. They have already managed to gain some positive results through this work, as Miglietta observes: "New data has now been obtained using sophisticated measurement technologies, such as mass spectrometry used for studying high-molecular weight compounds and a proton-rate mass spectrometer which supports the analysis of volatile compounds".

There is potential for the use of biochar at both the industrial and agricultural scale, and use it as a replacement for domestic compost as compost is thought to most likely amplify the modifying properties of biochar. Mixtures of the two materials that make up biochar and compost are also currently being scrutinised for potential large-scale applications within the agriculture sector. The infrastructure that is required for mass adoption of biochar does not currently exist – there are no large biochar production plants in place yet in Europe. However, according to Miglietta, the TC and HTC systems both have great potential to be further developed and reach large industrial scales: "Several stakeholders are considering these two technologies as promising avenues for large investments. Some resources have now been invested in pilot systems throughout Europe in order to progress this".

The current European agricultural policy does not yet assess the use of biochar in its attempt to reduce carbon emissions; however some individual countries are giving serious consideration to biochar as a viable option. Miglietta points out that the EU Commission is currently funding new research and a coordination action to explore standardisation aspects needed to support the incorporation of biochar into agricultural policy. There is every possibility that this product will become just a normal part of agricultural business in the future, and at the same time help to improve the sequestration of atmospheric carbon.

EUROCHAR

BIOCHAR FOR CARBON SEQUESTRATION AND LARGE-SCALE REMOVAL OF GREENHOUSE GASES (GHG) FROM THE ATMOSPHERE

OBJECTIVES

To investigate carbon sequestration potentials that can be achieved by transforming plant biomass into charcoal (or biochar) and add that to agricultural soils. Biochar production will be demonstrated using thermochemical or hydrothermal carbonisation processes that can produce energy and store 15-20 per cent of the carbon originally contained in the biomass.

PARTNERS

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DR FRANCO MIGLIETTA has a background in agronomy and terrestrial ecology. He developed innovative approaches in elevated-CO_2 research, in terrestrial carbon-cycle science and in climate change mitigation strategies. Since 2010 he has held the role of Scientific Director of FoxLab, a joint research collaboration between CNR and the Fondazione E Mach in San Michele all' Adige, Italy.