HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 358 July 2010

Biochar

Biochar is carbon rich material made by heating organic matter in low oxygen conditions. It may have the potential to reduce levels of atmospheric carbon dioxide (CO_2), thus helping the UK to meet its greenhouse gas emissions reductions targets. Furthermore, applying biochar to agricultural land could improve soil fertility, although research is far from definitive as results are variable. This POSTnote examines the current status of research into the production and use of biochar, the feasibility of using it to combat climate change, and any unintended consequences that may result.

Overview

- Biochar is a carbon rich charcoal-like substance created by heating plant matter in low oxygen conditions.
- Adding biochar to soil sequesters carbon and may improve soil condition. However, few soil application studies in the UK have lasted even 10 years; long-term implications remain unclear and more conclusive studies are needed.
- The carbon sequestration potential of biochar in the UK is about 3.6 Mt CO_2 a year using only wastes and residues. There is additional potential from purpose-grown crops, but land use change emissions could cause a carbon debt.
- Financing biochar may require government incentives unless it becomes eligible for carbon credits (for example, under the Clean Development Mechanism).
- Biochar is currently classed as a waste product of bio-energy production and as such, its use is limited under the EU Waste Framework Directive (2006).
- Regulating the production of biochar would allow it to be applied to soils in the same way as compost.

Background

CO_2 released by human activities makes up about 70% of greenhouse gas (GHG) emissions.[1] In 2008, the UK released 530 million tonnes (Mt) of net CO_2 into the atmosphere.[2] For the UK to meet its legally binding target to reduce GHG emissions to at least 80% below 1990 levels by 2050, they must decline by 410 Mt to around 120 Mt. Current methods of lowering emissions include moving to a low-carbon energy supply and increased energy efficiency.[3] Forestry and agriculture also have the potential to reduce atmospheric CO_2 by using forests and soils as a carbon 'sink'. Carbon, in the form of biochar, can be mixed into soils, significantly reducing the rate of return to the atmopshere. This means that carbon is released into the atmosphere much more slowly than it is removed, leading to more carbon in soils and a net reduction.

Biochar

Biochar is a carbon rich charcoal-like substance created by heating biomass (organic matter) in low oxygen conditions, a process known as pyrolysis. Almost half of dry biomass weight is pure carbon. If biomass is left to decompose in air, almost all of the carbon is lost into the atmosphere within a few years. During pyrolysis, around 50% of biomass carbon is converted into biochar. Of the other 50%, around two-thirds can be released as useful energy. Thus 1 Mt of dry biomass sequesters (locks away) 0.3 Mt of carbon, equivalent to 1.2 Mt CO_2.

Using Biochar to Address Climate Change

Biochar is considered a potential climate change mitigation technology because it removes CO_2 and simultaneously releases energy (Box 1). It would be 'carbon negative' if its use sequesters more carbon than it emitted. To be considered truly carbon-negative, a biochar system must also take into account emissions resulting from biomass growth, collection, pyrolysis, spreading and transport. This is done using “Life Cycle Assessment (LCA)”, which estimates the cumulative life-cycle energy and GHG emissions balance and also its economic feasibility.

In the UK, biochar can be produced using biomass from biowaste (which includes biodegradeable municipal and agricultural waste) or purpose-grown re-growing biomass plantations such as willow.

Box 1. Energy Produced During Pyrolysis

Pyrolysis gas is one outputs of pyrolysis and consists primarily of carbon monoxide, carbon dioxide, hydrogen, and other trace gases. It can be used directly as a fuel source to heat the pyrolysis unit for biochar production. Up to now, on a small sale, is has been used as an intermediate for synthesising liquid fuels and industrial chemicals, such as methanol, synthetic petroleum or diesel.

Biorefining involves using organic matter for fuel/energy generation in addition to producing useful chemicals and end-products like biochar. Although the concept is in its infancy, under a biorefinery system, the carbon and energy savings would be cumulative. For example, bio-oil is a carbon-rich liquid fuel which can be used as a substitute for fossil fuels for providing heat, electricity and/or chemicals. With some modifications to the equipment bio-oil can be an acceptable substitute for diesel fuels, for example in static engines. Bio-oils can also be upgraded to transport fuels.

Waste Biomass

There is almost 50 Mt of biomass feedstock suitable for biochar production available in the UK each year.[4] This includes crop and forestry residues, and wood, animal and biodegradable municipal waste. If it were all maximised for biochar production, atmospheric CO_2 could be reduced by 60 Mt per year. However, large volumes are already allocated elsewhere. These include:

- electricity generation – biomass can be burnt in power stations, helping to meet the UK’s renewable energy commitments.[5]
- anaerobic digestion – biomass is broken down by bacteria in the absence of oxygen to produce heat or methane. The residual solids can be treated and used as a soil conditioner and fertiliser.[6]
- return to soils – residues enrich soil organic carbon, increase soil moisture and decrease risk of erosion, there by restoring quality and increasing yield.

Although electricity generation and anaerobic digestion can form part of a biochar production system, less carbon may be sequestered as a result. A more plausible estimate of biomass available for biochar production is around 3 Mt, which assumes just 25% of crop and forest residues with no wood, animal or municipal waste.[4] Using this figure, the total CO_2 reduction amounts to around 3.6 Mt a year.

Biomass Plantations for Producing Biochar

Given some of the other uses of waste, purpose-grown re-growing biomass plantations may be an alternative. The most commonly discussed options in the UK are fast growing willow or perennial grasses. Most plantations are monocultures; an alternative would be to plant mixed forests, especially of locally native species. This would minimise the risks associated with non-native species such as decreased biodiversity and disease transferral but may decrease the amount of biomass available.[7] However, LCAs of biochar production comparing waste and a purpose-grown crop (switchgrass) shows that the carbon required to process the crop is greater than the total volume of carbon sequestered. Whether this is the case for other biomass crops has yet to be investigated.

Emissions from Land-Use Changes

Land converted from forests and grasslands into agricultural land for growing biomass crops may generate a ‘carbon debt’ that could take years to pay back. Changes in land use lead to GHG emissions and account for 5.9 Gt of annual CO_2 emissions worldwide.[8] However, the debt can be minimised if biomass is harvested from purpose-grown crops grown on degraded or idle land.

Competition for Land

The government’s UK Biomass Strategy acknowledges that increasing demands will have implications for land use, biodiversity, the environment and the landscape.[9] There is concern about land availability to produce enough biomass to meet the UK’s targets for bioenergy and biofuels.[10,11] Biomass requirements for biochar from plantations would be in addition to this, putting further pressure on the land.

A farmer’s decision to sell his/her crops as a food supply or to a biodiesel or ethanol processor for biofuels is largely dependent on price. In 2009, around 25% of the total grain produced in the US was used for fuel ethanol. ActionAid (an international charity whose aim is to fight poverty across the world) have attributed 30% of global rises in food prices in 2008 to increasing demands for biofuels, pushing 100 million people into poverty and 30 million people into hunger.[12] Growing biochar specific crops in place of agricultural food crops may further aggravate the competition for land.

Obtaining Biomass

In the UK, developers of dedicated biomass powerplants and those that use both fossil fuels and organic matter must report annually on biomass use, origins, and whether it has come from any accredited sources. 99% of biofuel feedstocks generated in the UK currently meet required standards. However, only 4% of fuel from feedstock cultivated outside the UK meets these standards. The Soil Association has suggested issuing farmers with a licence to produce biochar, with farm-specific restrictions on the source of biomass, preventing them from converting land used to grow food crops into land for growing biochar biomass.[13] They propose annual assessments to verify that biochar production is in line with restrictions and to re-issue licences, which could be incorporated into the Soil Association’s current farm inspections.

Displacement

Given the pressures on land availability in the UK, large scale biomass plantations for biochar would probably be located abroad. The Gallagher Review, a study on the impacts of biofuels, emphasises the need to concentrate on using idle or marginal land for biomass plantations. Often however, land that is considered idle is actually being used by local subsistence farmers.[14] In Mozambique, 13 million hectares of land that was put up for bidding and bought or leased by overseas buyers over 18 months, was actually being used by local communities, who have no legal claim. These conflicts are yet to be resolved and there are concerns that similar situations may arise as demands for land increase. Using imported biomass is unlikely to be a viable option as carbon sequestration would be at least partially negated by transport emissions. Reducing atmospheric carbon could be is maximised by producing biochar close to the site of biomass collection.

Applying Biochar to Soils

At the 2009 United Nations Climate Change Conference, the EU endorsed the use of soil and forests as carbon sinks as part of the Copenhagen 2012 settlement. Projects on small-scale farms are being run to investigate the potential of this further (Box 2).

Stability of Biochar in Soils

When biochar is added to soil, a portion of it degrades, allowing carbon to escape back into the atmosphere. Scientists are currently studying the properties of carbon found in soils from hundreds of years ago to help shed light on the factors that are important for long-term stability.

Pockets of fertile agricultural land in the Brazilian Amazon are the result of *terra preta* ('black earth') soils, which were created hundreds of years ago by mixing organic wastes like charcoal (amongst other things) into soils. Research has shown that adding biochar to crop soils can mimic some of the effects of *terra preta* by:

- adding available nutrients;
- improving nutrient retention;
- enhancing water retention and hence availability;

leading to a boost in crop yields and preventing nutrients from being leached into rivers/waterways. Although the carbon in *terra preta* soils has been dated as being over a thousand years old, it is not clear how much has already been lost.

Some experts highlight that across the world where wildfires are common, the amount of carbon in soils is less than expected as a result of the fires. Biochar is generally considered to be stable to the magnitude of hundreds, and in some cases, thousands of years. However, experimental long-term studies are absent; there are concerns about a lack of understanding of the long-term outcomes and stability of biochar carbon.

Box 2. Small Scale Projects to Sequester Carbon: From 'Slash-and-Burn' to 'Slash-and-Char'

Slash-and-burn farming involves cutting down trees and burning them to free land for agriculture. This is usually farmed for just a few years until its fertility declines and it is left fallow to recover. As a result of population increases and demand for land, fallow periods have decreased, leading to a drop in soil fertility and crop yields. The result is that farmers shift much quicker, deforesting and burning more land and releasing substantial GHGs as they go. Slash-and-char involves pyrolysing the cleared biomass to create biochar instead of burning it. If biochar addition to soils improves land fertility and crop yield, then applying it to the newly created agricultural land would lengthens the time that farmers can use that land. The process reduces deforestation and sequesters carbon.

Case study 1: Congo[15]

Some 200 subsistence farmers in Congo are working with ADAPEL (Action pour le Développement de l'Agriculture et de la Pêche Avec Protection Environnementale de Likende), The Biochar Fund and Biochar.org to use slash-and-char in place of slash-and-burn.

The project will use around 10 tonnes of agricultural residues and cleared vegetation to produce 3 tonnes of biochar per day, increasing soil carbon content by 1% and sequestering 3,500 tonnes of carbon. Currently, farmers use a plot of land for between one and three years before moving. The hope is that by implementing slash-and-char farming, farmers will remain on the same plot of land for twice as long and increase crop yields by 50-100%.

Case study 2: Belize[16]

The Toledo Cacao Growers Association (TCGA) and Carbon Gold are working on a project that provides cacao farmers in Belize with financial incentives to process their cleared biomass and agricultural waste (cacao and shade tree prunings) into biochar. The biochar produced is mixed with a locally produced soil supplement (made using composted lemon pulp and naturally occurring microorganisms), and applied back to the soil which, together with increased pruning, has improved plant yield.

There are around 1200 small-scale Fairtrade cacao farmers in Belize, typically farming a 1 hectare area of land with 5 hectares of slash-and-burn in reserve. Every year, farmers generate enough biomass to produce 3 tonnes of biochar from prunings and 15 tonnes of biochar from slash-and-char. Farmers are paid $75 per tonne of biochar they produce, boosting their annual income by 84%. They also benefit from increased crop yields resulting from biochar application. The scheme is being piloted with a selection of farmers but the hope is to implement it with all 1200 during 2010. Green & Black's support the project by purchasing the emissions reductions generated to offset its annual carbon output.

The International Biochar Initiative (IBI)[17], an organisation formed to produce standards and classification and evaluation systems for biochar production and use, advocates using agricultural and forest waste biomass to produce biochar. Globally, huge volumes of crop residues are burned each year, for no other use than to get rid of them. For the purpose of sequestering carbon, the IBI has stated that it "doesn't matter if the average stability of biochar is 500 or 1000 years" and that it only "becomes critical if it falls significantly below 100 years".[18]

There are a few studies showing biochar stability of less than 100 years. Proponents argue that short lifetime estimates are due to differences in the formation of the biochar, the types of feedstock used, the soils it is applied to, temperature and downward and sideways movement of biochar through the soil. This highlights the importance of conducting long-term studies on different soil types using different feedstocks.

Benefits of applying Biochar to UK Soils

Experimental work on the beneficial properties of adding biochar to soils has largely been conducted outside of the UK, in tropical climates and on relatively unproductive or infertile land. With the UK's temperate climate more productive soils, it is not clear whether the same benefits would result. UK agricultural benefits may come from decreased fertiliser needs by increased fertiliser efficiency and reduced drought stress in drought prone areas.

The UK government's Foresight Land Use Futures report recommends financially rewarding agriculture for providing wider benefits, including climate mitigation through carbon sequestration.[10] Natural England (an independent public body whose purpose is to protect and improve England's natural environment) suggests the development of agri-environment schemes that reduce and sequester GHGs.[19]

Financing Biochar

In 2009, the United Nations Convention to Combat Desertification submitted a proposal to the United Nations Framework Convention on Climate Change to have biochar classed as a Clean Development Mechanism (CDM) project.[20] This would enable the UK to invest in and implement biochar in developing countries. Certified emissions reductions credits, equivalent to one tonne of CO_2, are issued to the investing country and count towards meeting emission reductions targets. The host country benefits from investments in its infrastructure. The purpose of CDM projects is to encourage emission reductions that would not have occurred without the additional incentive provided by those credits.

Calls for biochar to be classed as a CDM project along with afforestation and reforestation have so far been rejected by the UN. There are concerns among both proponents and opponents that schemes will be difficult to monitor. Assuming that the science of biochar addition to soil is "unambiguously beneficial", the Soil Association supports the view that agriculture should be rewarded for carbon sequestration through biochar. However, before biochar can be eligible for any kind of carbon 'credit', the exact volume of carbon sequestered, and for how long, will need to be verified. Doing so is complex; at present there is no reliable method to measure how much carbon has been stored and how much could be lost back into the atmosphere during (for example) the first 100 years.

Food Shortages

Biochar proponents have stressed that the value of carbon credits or incentives must be such that growing crops solely for biochar production is not a financially viable option. The IBI has stated that any land-use changes that "replace food crops would not qualify for carbon credits if indirect land use change occurs because the carbon debt would offset the benefits of sequestration, as shown for biofuels".[17]

Regulation

Biochar Production

Biochar production using material classed as biowaste will need a permit under the Environmental Permitting Regulations (England and Wales) 2007 if it is considered a waste management technique. Environment Agency permits are intended to ensure that such activities do not cause harm to human health or the environment..

Soil Application

At present, biochar is regarded as a by-product of bio-energy production, and it is likely to be classified as a waste. As such, its use might be limited under the EU Waste Framework Directive (2006). Compost can be used as a non-waste product if used in accordance with the Compost Quality Protocol. If biochar is used as a soil amendment in a way similar to compost, additional protocols for biochar will need developing by the Environment Agency and the Waste and Resources Action Programme.

Health Risks Associated with Biochar

Biochar can contain polycyclic aromatic hydrocarbons (PAHs): a group of toxic chemical compounds, some of which have been identified as carcinogenic. Toxic compounds in biochar could potentially pass into soils, plants and the food chain.

Biochar is also a form of black carbon that can accumulate in the lungs as a result of prolonged inhalation. Black carbon has been declared as *possibly carcinogenic to humans* by the International Agency for Research on Cancer. In a two year biochar field trial in Canada, approximately 30% of biochar was lost during handling as wind-blown dust. Although likely to be due to inappropriate soil incorporation techniques, this highlights some of the potential health risks associated with biochar. As such, robust and regularly monitored health and safety guidelines will be necessary for anyone involved in the biochar process.

Endnotes

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16 Carbon Gold, http://www.carbon-gold.com/
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19 Natural England (2009) *Farming with Nature.*
20 POSTnote 354, *Global Carbon Trading*

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Swati Nettleship for researching this briefing, to Natural Environment Research Council (NERC) for funding her parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Jonathan Wentworth.