The Terra Preta phenomenon

Ray O'Grady[1] and **Rod Rush**[2]
DesertSmart Technologies*
[1] rogrady@bigpond.net.au
[2] rodrush@bigpond.net.au

Abstract

The greatest legacy the Amazonians left to the World was not the famed 'City of Gold' but the Terra Preta. These man-made 'Indian black earths' cover an area the size of France. They hold a secret to carbon sequestration that could reduce carbon dioxide emissions and global warming.

We require only 10% of our productive, degraded lands to absorb the estimated 6.1 gigatons of carbon dioxide of emissions to make a carbon negative world possible in our life-time.

If we open our eyes, increase our understanding of how we can generate carbon negative fuels and scrub fossil fuel emissions of pollutants, we can reverse our historic increase in atmospheric carbon. The question must then be asked: 'Do we need nuclear power to reduce Global Warming?'

The micro pores and cracks in charcoal provide two important resources for the soil microbial community – a source of entrapped nutrients and 'safe housing' for the protection of beneficial bacteria from grazing protozoa. The activated portion attracts and holds nutrients for the microbes, 'like having food home delivered'.

In most situations when charcoal is used in combination with inorganic or organic fertilisers, crop yields increase from improved fertiliser efficiency by reduced nutrient loss from leaching.

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Introduction

The re-evaluation of the inert carbon pool or 'useless charcoal' has been largely inspired by research on the 'Terra Preta phenomenon' by the Lehmann Laboratory at Cornell University, Eprida Inc and other like-minded organisations that have embraced the 'legacy of knowledge' held in these 500-2,500 year old, man-made Amazonian black earths, first described by Professor Charles Hartt in 1874 (Lang 2006).

Secrets of El Dorado – video highlights

After spending eight months drifting through the Amazon in search of the Indians' famed 'City of Gold' in 1542, Francisco de Orellana reported to the Spanish court:-

"there could be seen very large cities that glistened in white …. many roads that entered into the interior …. and besides this, the land is as fertile …. as our Spain."

The mystery surrounding Orellana's discovery has been debated for centuries, mostly with disbelief …. how was it possible, even with today's technology to feed such large populations in a region with such poor soils as in the Amazon? …further confounded by reports of some fifty years after Orellana … that no cities could be found only scattered native hunters and gatherers. (Secret of El Dorado 2003).

The answer lies hidden in the Terra Preta (Indian black earths) beneath the dense Amazon jungle. Researchers have now discovered that these Terra Preta soils cover an area the size of France and were made by the indigenous population well over 500 years ago, using a combination of charcoal and organic matter (Butler 2006).

The Terra Preta phenomenon has inspired research into carbon sequestration in the soil, new slow release and more efficient fertiliser technologies, nutrient retention and thus improved soil health.

Eprida Inc is just one group that have proposed that agricultural wastes as well as bio-energy crops could be used to produce hydrogen and char by burning them in specialised power plants. This revolutionary energy efficient process could be combined with coal and capture about 60% of the CO_2 in the fume gas. This process could become a net sink for atmospheric carbon dioxide and provide carbon and a slow release fertiliser to enrich our soils. (Day 2004)

Charcoal production

Charcoal making is an old and honourable trade, with its origins lost in antiquity. Almost half the world's population still depend on charcoal for cooking. Modern carbonisation plants claim higher yields and faster operation allowing new raw materials to be carbonised with less pollution and a greater chemical recovery.

Nature's way of retaining fertilisers in the soil

The application of charcoal to the soil can improve soil fertility as it usually contains some potassium, phosphorus and trace elements in the ash (Table 1a). However, the most significant advantage is the ability of charcoal to increase the nutrient and organic matter holding capacity of the soil. In most situations, when charcoal is used in combination with inorganic or organic fertilisers, crop yields increase from improved fertiliser efficiency and reduced nutrient loss via leaching into lower soil horizons and ground or surface water (Table 1b, 2 and 3). Reduced water pollution is an added benefit.

Table 1a. Soil properties after harvesting the crop of soybeans in Indonesia (see Table 1b).

	pH	**Exchangeable cations (mg/100g soil)**		**Maximum water holding capacity %**
No charcoal	4.7	Potassium = 50	Magnesium = 4.1	40
With charcoal	5.1	Potassium = 70	Magnesium =10.4	47

Table 1b. Field trial soybeans Indonesia.

	Yield t/ha	Relative ratio
No charcoal	0.65	100
With charcoal	0.85	131

No basal fertiliser applied
Charcoal 10t/ha broadcast
(from Association for International Co-operation in Agriculture and Forestry, Japan online)

Table 2. Field trial for soybean in Thailand.

	Yield t/ha	**Relative ratio**	**Number of root nodules**	**Relative ratio**
No charcoal	1.56	100	777	100
With charcoal	2.18	138	1,212	156

Basal chemical fertiliser applied 19kg N, 24kg P and 30kg K
Charcoal 10t/ha broadcast
(from Association for International Co-operation in Agriculture and Forestry, Japan online)

Table 3. Relation between charcoal amendments to soil and crop responses (from Glaser, Lehmann, & Zech 2002)

Treatment	Charcoal t/ha	Relative biomass %	Crop/Plant	Soil Type
No Charcoal	0	100	Bauhinia wood	Alfisol/Utisol
Charcoal	Unknown	113	Bauhinia wood	
No Charcoal	0	100	Soybean	
Charcoal	0.5	151	Soybean	Volcanic ash–loam
Charcoal	5.0	63	Soybean	
Charcoal	15.0	29	Soybean	
No Charcoal	0	100	Pea	
Charcoal	0.5	160	Pea	Delhi Soil
No Charcoal	0	100	Moong	
Charcoal	0.5	122	Moong	
No Charcoal	0	100	Cowpea/Oats/Rice	Sand
Charcoal	33.6	127	Oats	
Charcoal	67.2	120	Rice	
Charcoal	67.2	150	Cowpea	Xanthic Ferrasol
Charcoal	135.2	200	Cowpea	
No Charcoal	0	100	Sugi Trees	Clay Loam
Wood Charcoal	0.5	249	Sugi Trees	
Bark Charcoal	0.5	324	Sugi Trees	
Activated Charcoal	0.5	244	Sugi Trees	

Soil biological health

The micro pores and cracks in charcoal provide two important resources for the soil microbial community i.e. a source of entrapped nutrients and 'safe housing' for the protection of beneficial bacteria from grazing protozoa. The activated portion attracts and holds nutrients for the microbes, 'like having food home delivered.'

Research by Wardle (1998 cited by Pietikäinen *et al.* 2000) showed an increase in substrate-induced respiration under charcoal, indicating there were interactions between soil microbes and charcoal. Under these conditions soil microbial diversity is encouraged, improving soil heath, reducing crop losses from soil borne diseases and suppressing root-feeding nematodes.

Clean energy, fertiliser and charcoal project

The United States National Renewable Energy Laboratory and Eprida Inc have demonstrated how the physical structure and the highly absorbent state of partially activated charcoal provides the framework for building an NPK fertiliser inside the char's pore structure (Day & Evans, 2002 US patent application). Patent applications have also been lodged in over 30 other countries.

When used as a carrier for nitrogen compounds such as NH_4^+, urea, or ammonium bicarbonate and other plant nutrients, carbon forms a slow release fertiliser that is ideal for plant growth. One example is a solid granulated Ammonium Bicarbonate-Char fertiliser.

The inorganic carbon (HCO_3^-) content of the ammonium bicarbonate (NH_4HCO_3) – char fertiliser is non-biodegradable by soil microbes in certain soils and remains in the soil as long term sequestered carbon. The key step in this technology is a NH_3-CO_2-H_2O reaction system to form a solid NH_4HCO_3 – Char fertiliser product.

Charcoal and long term carbon sequestration

Charcoal is very stable at ambient temperatures, even on geological time scales. It is estimated that charcoal has a half-life in soil of 5,000 years.

A symposium (EACU) at the University of Georgia in Athens, GA, USA brought together a group representing scientists from chemistry, archaeology, physics, anthropology, microbiology, soil science, agronomists, renewable energy research and representatives from the DOE, USA and Industry. The focus was to look at the evidence for massive historical carbon utilisation, current research and how carbon negative energy could be economically deployed today (Day 2004).

If we just open our eyes and increase our understanding of how we can generate carbon negative fuels, scrub fossil fuel emissions from powerhouses of pollutants and carbon dioxide, we can reverse our historic increase in atmospheric carbon.

Obersteiner (2004) estimated that we require only 10% of our productive, degraded lands to absorb the estimated 6.1 gigatons of carbon dioxide emissions to make a carbon negative world possible in our life time. The question must then be asked:

Do we really need nuclear power to reduce Global Warming?

Benefits

Suggested benefits of soil carbon include:

Building soil fertility as measured by:

- nutrient and water holding capacity;
- microbial populations and diversity;
- buffering of excessive levels of some nutrients through the build up of soil organic matter levels and associated soil biology e.g. salt.

Reducing nutrient and chemical leaching to lower soil horizons and ground water by:

- the action of the carbon input;
- microbial and organic matter capture of minerals;
- microbial degradation of organic chemical inputs.

Increasing plant access to soil nutrients by:

- mycorrhiza and other microbes accessing tied up nutrient sources;
- reduction in soil compaction;
- increasing soil aeration.

Decreasing the amount and therefore the cost of inputs for plant production by:

- retention of inputs by the carbon and increased organic matter and associated soil biology;
- increasing plant access to previously tied up nutrients;
- decreasing chemical interventions to ward off diseases.

Decreasing wind and soil erosion by:

- increasing soil aggregation and aggregate stability via mycorrhizal and other microbial activity.

Stabilising degraded landscapes e.g. construction and mining sites by:

- using carbon and biological landscape rehabilitation techniques.

Increasing the quality of waste water by:

- removal of a range of toxic substances from urban and industrial waste water by treatment with low cost activated carbon;
- bioremediation with diverse and active soil microbial populations.

Reducing air and water pollution associated with intensive livestock production by:

- treatment of wastes with activated carbon.

Conversion of the wastes of intensive livestock production into stable and valuable soil inputs by:

- capturing the leachable mineral and volatile ammonia content with activated carbon.

Long term sequestration of carbon leading to a reduction in greenhouse gases by:

- conversion of solid waste streams into carbon which remain in the soil for very long periods e.g. up to several thousand years;
- sequestration of carbon dioxide into organic matter pools in the soil that recycle but remain relatively constant under sustainable agricultural practices.

Reducing landfill requirements for organic wastes by:

- converting organic wastes into useful carbon products.

Reducing ground, water and atmospheric pollution from the breakdown products of organic wastes by:

- converting organic wastes into carbon products;
- mixing some of the wastes with activated carbon to sequester their volatile ammonia content.

***DesertSmart Technologies** combines the sciences of pyrolysis, waste management, fertiliser technology, soil biology and ecology, irrigation management and applied agriculture science. DesertSmart Technologies takes a holistic approach to organic waste resource utilisation for a sustainable integrated bottom line.

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