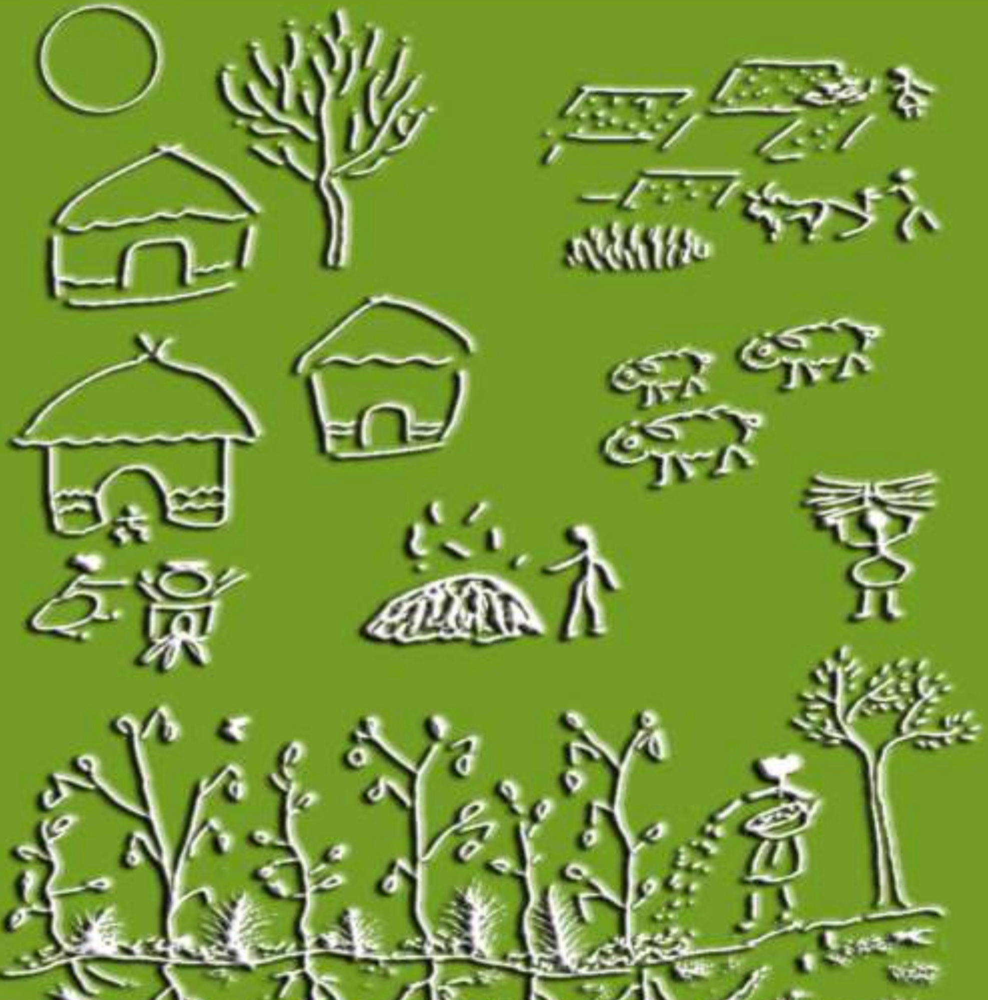
BIOCHARCULTURE

Biochar for Environment and Development



SAI BHASKAR N. REDDY

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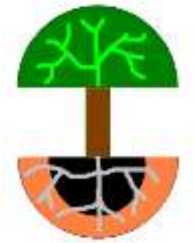

Biocharculture

Biochar for Environment and Development

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Front & Back cover: Diagrams depicting the integration of biochar as part of life.

Note: The author drew sketches and mostly took the photos presented in this book.

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For 'The Earth'

Preface

Here is a question often asked with great concern: can agriculture meet the challenges of an expanding world and a global economy that is moving more to ‘middle income’? The projections by the Food and Agricultural Organization for instance are that by 2050 the demand for food and fibres - compared with 2005 - will have expanded by 60% respectively 81%. Is this a challenge that is too hard to meet?

A recent comprehensive review of co-optimizing solution for food, water and energy by the World Business Council for Sustainable Development[1] found that we still have many co-optimizing options in hand, but it also means that we need to rejuvenate the way farming is done. Agriculture needs to be more precise. It needs to be better integrated in the landscapes that it is part of and it should be supporting rather than substituting natural processes.

It is in this regard that I am very happy to introduce this book on Biocharculture and also to acknowledge its unfailing energetic author, Sai Bhaskar Reddy. We are happy that much of his overall insights and first hand experiences have become available through this book.

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[1] http://www.wbcsd.org/work-program/sector-projects/water/waterenergyfood.aspx

Biocharculture falls very much in a vision of an agriculture that supports and makes use of natural growing mechanism. Biochar is charcoal that is used for other purposes than heating. It can be a by-product or part of an entire production system.

Biochar scores on many fronts: it improves the capacity of the soil to retain moisture but also nutrients, such as nitrogen and phosphorus. It helps regulate soil temperature and contribute to climate change mitigation. It improves soil life. I still remember that Sai Bhaskar explained a tiny piece of charcoal to me as being a 'skyscraper for millions of soil biota'. There is still a world to gain – by better understanding this miraculous microbial world and the way our soils and landscapes work and this book hopes to contribute and give practical suggestions and directions. Interesting in some parts of the world biochar is part of the production process where in other it is not. In other words we need to create new traditions and farming cultures, as this book very much argues.

Frank van Steenbergen
Director, MetaMeta

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Introduction

Biochar research inspired the development of a revolutionary technology that can have tremendous impact on agriculture, water, habitats, energy, health, sanitation, livelihoods, environment, and carbon sequestration. This book contributes to the understanding of biochar as a resource. Although the term "biochar" has only recently been adopted, it is a very well known concept. Biochar has long been part of some of the best practices in traditional agriculture in different parts of the world. People have used it for many purposes, including soil fertility management. Recently, biochar has attained greater importance as a result of discoveries about biochar use in the past and ongoing scientific research about its characteristics.

☐ On understanding biochar; background; research and definitions; biocharculture; relevance to agriculture

Picture 1 A fresh piece of biochar

This book highlights the diverse uses of biochar. Biochar is a traditional, cultural, sustainable, and adaptable practice and is not just a product for soil amendment. The term biocharculture was coined by the author.

The application of biochar to soil enhances its fertility and enables long-term carbon sequestration. And also offering an innovative opportunity to enhance the living conditions of rural families. Additionally, these effects counteract deforestation, protect biodiversity, increase crop production, improve agricultural waste management, and remove carbon from the atmosphere—functions that are crucial to a carbon-negative strategy to fight global warming.

Common substances like soil microbes, pottery shards, bones, urine, mulch, compost, manure, and silt used to be integral parts of biochar. In the recent past, these were replaced by non-disclosed elements.

Biochar is sold as a commercial product under different names, generating some confusion about the substance. It would be difficult for biochar to become a culture like Terra Preta unless pragmatic practices are evolved to adapt to the present context.

Biocharculture is a holistic approach that has been historically tested, traditionally practiced, is culturally integral, economically viable, socially responsible, environmentally sustainable, and agreeable as a policy.

Background

Biochar is produced after pyrolysis of biomass, typically within a temperature range of 300°C to 800°C (Barnikv). Biochar formed within this range is the most valuable. At relatively lower temperatures, a higher percentage of the biomass gets converted into biochar. At higher temperatures, some part of the biomass is converted into energy, producing less quantity of biochar. As such, the design of the pyrolysis kiln or retort is important in determining temperature range and biomass to biochar conversion efficiency.

In rural areas where biochar is simply the end-product left behind after meals have been prepared on biomass stoves. Stove design determines the rate of energy generated, biochar and ash produced as byproducts. The author has designed over 50 biomass cook stoves based on materials available in rural sites. With its higher efficiency, a typical 'good stove' reduces biomass fuel consumption and produces 16% to 25% biochar of the original biomass used as fuel by weight.

Research has shown that the benefits of biochar include improvement in soil productivity, long-term soil carbon sequestration, reduction in greenhouse gas (GHG) emissions, and reduction in loss of nutrients by leaching (Lehmann et al., 2006). Biochar is known to have high cation and anion exchange capacity (CEC and AEC respectively) and adsorption and absorption, which improves nutrient use efficiency when biochar is applied to the soil. Biochar is particularly beneficial in sandy soils and highly weathered clay soils with low native CEC and AEC and low fertility. Biochar also acts as a source of small amounts of P, K, and other nutrients (Lehmann et al., 2003; Lehmann et al., 2002). Soil pH is an important factor in determining the bioavailability of nutrients, and biochar is known to raise soil pH (Chan et al., 2008), thereby improving the availability of nutrients to crop plants. Biochar compost has a very high soil microbial density, which balances and brings the soil pH close to neutral over a period of time. Biochar compost can be applied to all types of soils, i.e., acidic, basic, and neutral soils. It has been reported to adsorb harmful chemical compounds from the soil, such as phytotoxins and nitrification inhibitors, and improve plant growth. Biochar is also reported to enhance the microbial population (Wardle et al., 1998; Zackrisson et al., 1996), and improve moisture holding capacity and soil structure (Piccolo & Mbagwu, 1990; Piccolo et al., 1996).

In the wake of rising carbon dioxide concentrations in the atmosphere and global climate change (IPCC, 2007), biochar's resistance to decomposition offers another ecological benefit. Biochar can remain in soil for extensive periods of time—from hundreds of years to millennia (Cheng et al., 2008; Saldarriaga & West, 1986). Glaser (2001) has reported that the Terra Preta soils contain up to 70 times more carbon than neighbouring soils. Radiocarbon dating of these soils show biochar dating back from 740 to 2,460 years (Saldarriaga & West, 1986). Research has shown reductions in GHG emissions (Singh et al., 2010; Spokas & Reicosk, 2009) and reduced losses of nutrients due to leaching (Laird et al., 2010) when biochar is used as a soil amendment, which adds further incentive for its use.

Definitions

The science of biochar is still emerging, so there is no single definition for the term. Biochar is another name for charcoal used for particular purposes other than combustion. Like all charcoal, biochar is created by the pyrolysis of biomass. Biochar's typical physical and chemical composition allows beneficial application in a variety of sectors. The following statements provide clarification:

- The term biochar is used mainly in the context of soil fertility enhancement and management

- The prefix 'bio' in biochar implies living, i.e., the microbial life in the 'char'.

- Biochar is the charcoal (carbonaceous material) produced from biomass for good use.

- Biochar is produced from biomass at temperatures between 300 to 800 degrees centigrade. Biochar produced as a byproduct in biomass cook stoves falls within this temperature range. The biochar produced at temperatures above 800 degrees centigrade or below 300 degrees centigrade can also be used for various purposes, but it is much less effective.

- The uses of biochar—as part of biocharculture—include its application in the areas of soil management, livestock, biomass energy, water purification, green habitats, sanitation, food, health, etc.

- As a geoengineering process, application of biochar addresses environmental and livelihood issues of communities. A porous material, biochar increases water retention, stimulates symbiotic nitrogen fixation in legumes, and creates a “cozy home” for bacteria, micro-organisms, fungi, minerals, and nutrients in general. This leads to improved nutrient supply for plants and reduced nutrient losses due to leaching (Glaser, 2002).

- Biochar, as a relatively stable form of carbon, is still found in ancient Terra Preta soils of the Amazon Basin, and thus could be considered as a long-term carbon sink (Lehmann, 2007).

Picture 2 Left - a nutrient-poor oxisol; right - an oxisol transformed into fertile terra preta using biochar.

Biocharculture

Biochar definitions are evolving; some are limited to explaining its use for soil amendment. In this book, the idea of biochar is adopted as a broad concept and the term “biocharculture” is used instead. This makes the idea more resourceful, and avoids casting biochar as merely a product used for soil amendment. As part of ‘biocharculture,’ the biochar can be used and reused in many ways and in the process address many important needs and benefits. For example, biochar in compost reduces Greenhouse Gas emissions, reduces leachate (and thus loss of valuable minerals), absorbs the urea/nitrogen, and, when finally applied to soil, enhances its fertility. The whole process brings about effective composting, Greenhouse Gases reduction, improvements in sanitation, and increases the overall value of biochar.

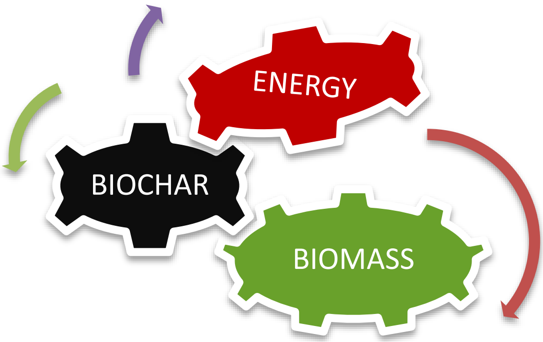
Biocharculture citation

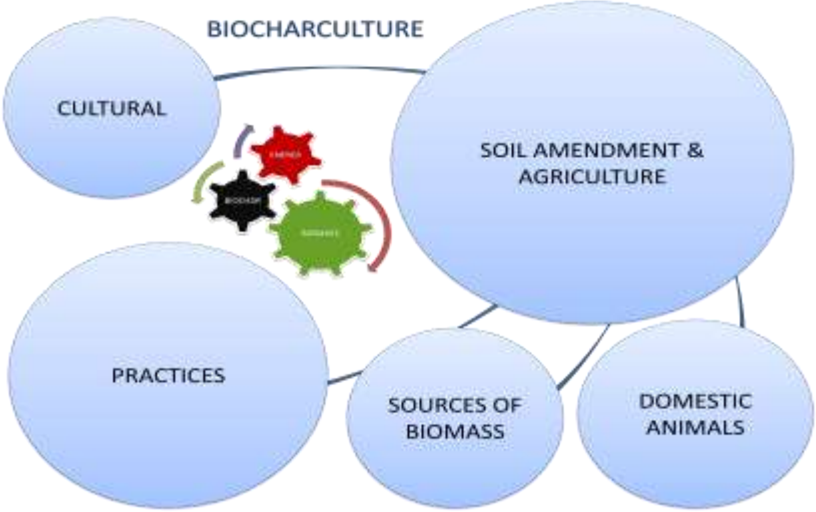
“To give credit to the term ‘Biocharculture,’ must acknowledge Dr. N. Sai Bhaskar Reddy, Geoecology Energy Organisation (GEO), Hyderabad, India, who has been successfully utilizing ‘Biochar compost’ for the past few years in his country. He is part of the ‘vanguard’ of a new biochar-based agricultural paradigm shift, away from ‘Green Revolution’ technologies and toward ‘holistic’ growing gardening / farming techniques and which also includes many, most of the Organic and Permaculture techniques.”

- Lloyd Helferty, Engineering Technologist, Principal, Biochar Consulting, 22 September 2012

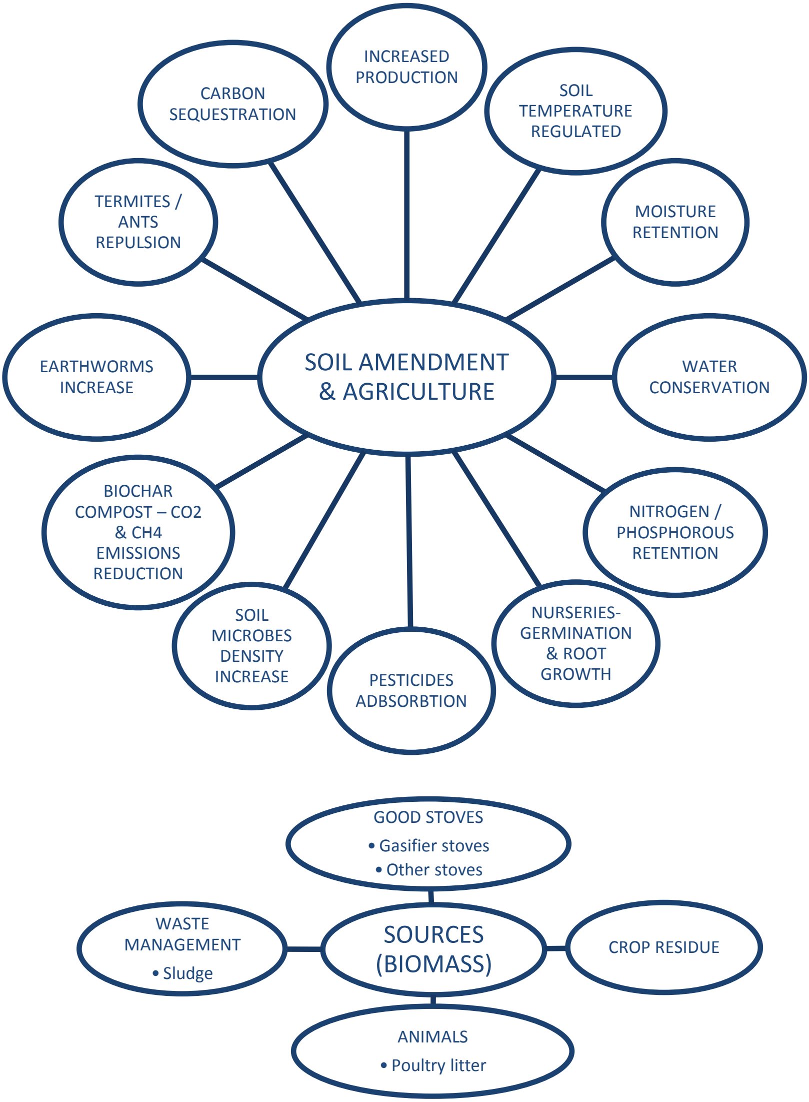
Picture 3 Author observing the evidences of biochar and pottery shards collected from a very old agricultural field

It takes time for biochar to become biocharculture if such practices do not exist traditionally. All the sources of charcoal as a byproduct from biomass cook stoves or other sources have always remained in the same environment and have been part of our daily life. The presence of biochar in a given place creates a positive environment. Biochar is derived as a by-product of a number of processes, such as burning of crop residue either intentionally, accidentally, or naturally burning of biomass as fuel in cook stoves. Biochar is used for sanitation-related purposes (in toilets / urinals; for cleaning teeth; for cleaning utensils; in producing 'biochar bricks' used in construction; in poultry bedding material and very small quantities in the feed; in refrigerators as pieces of charcoal for reducing odours etc.) Bamboo biochar, traditionally used by the Japanese, likewise has a variety of uses. Biochar products have not traditionally been commercial products, and have served multiple purposes before ultimately reaching the fields for use in improving the soil environment. The biochar ultimately ending up in the soil helps to address the problem of global warming through carbon sequestration. Biochar was not discovered suddenly. It can be adopted by farmers of all types. One should not rush to apply large quantities of biochar to crops expecting a bumper yield. Consistent, annual, incremental application is more sustainable for the farm and for the environment, unlike the manner in which chemical fertilizers have been applied over the last 50 years, which has rendered farms unsustainable and has even turned some into ecological disasters.

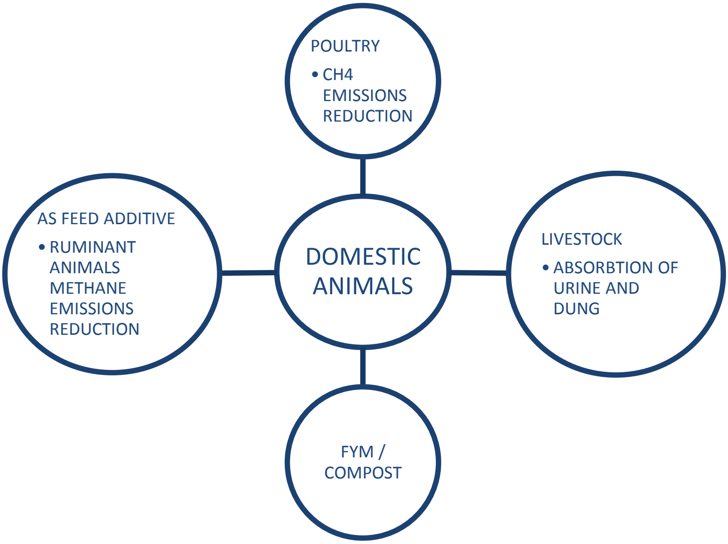


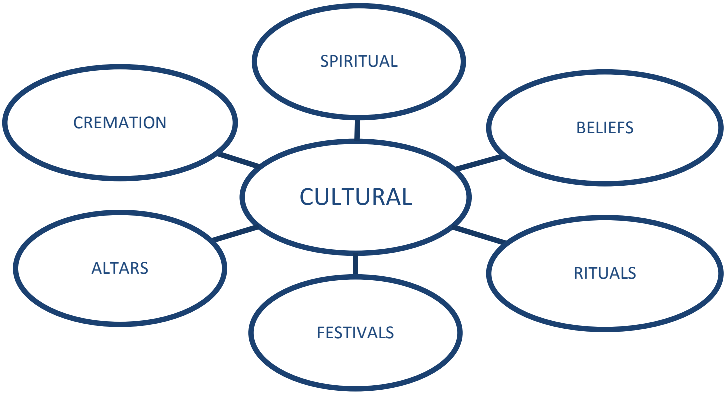


Picture 4 Depicting the factors relevant to biocharculture



Picture 5 Depicting biochar amendment in soil benefits and sources of biomass for biochar





Picture 6 Depicting biochar uses for domestic animals management and sources of biochar as a byproduct from cultural practices

Picture 7 Biochar uses as part of practices

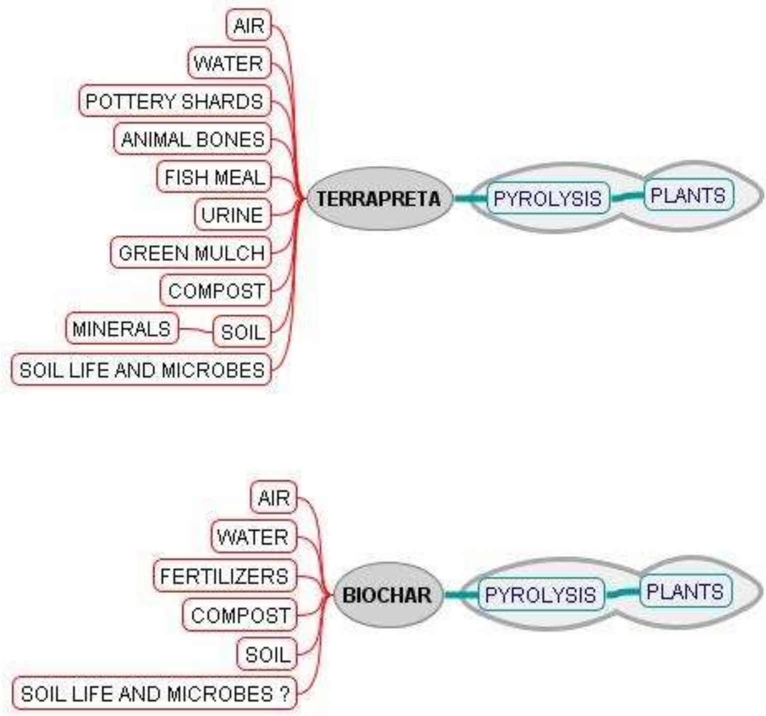
Biocharculture (bio + char + culture) is a broader representation of charcoal that covers all aspects relevant to its use.

Biochar versus Terra Preta

Picture 8 A freshly applied biochar in the soil

Biochar use is a millennias-old concept used by many cultures over the years. In the Brazilian part of the Amazon basin, charcoal burial dates back 2,000 years or more. Known as "Terra Preta" (Portuguese for "black earth"), man-made soils found at several sites in the region are still the more productive than anywhere else on Earth. Producing Terra Preta involves the application of stable organic matter in the form of biochar (biomass-derived black carbon or charcoal) in conjunction with nutrient additions. Such biochar is very stable, providing and retaining nutrients for millennia. Terra Preta was first described by Charles Hartt in 1874.

Until 2007, 'Terra Preta' was used to describe the process of using charcoal for soil amendment. The central question was 'Is it possible to recreate Terra Preta now?' The term 'biochar' has only been used extensively since 2007. Biochar is part of Terra Preta science, and charcoal is only one of the aspects the two have in common. Within the study of biochar, there is not much scope to discuss rural trash or cultural and traditional aspects of biochar's use, or to explain the presence of pottery shards, fish bones, silt, etc., in the soil. Terra Preta represents traditional wisdom and biochar is a modern science that is still evolving.



Picture 9 Terra Preta definition is broader than biochar

‘Terra Preta’ was produced when along with charcoal, rural trash consisting of pottery shards, fish bones, compost, manure, urine, silt, etc. was added to the less fertile acidic soils to improve their fertility. Rural trash in India had similar composition until recently. It was comprised of charcoal and ash from traditional stoves; pottery shards from roof tiles, pots, utensils, and cultural utilities; compostable biomass and urine from domestic livestock; fish and animal bones; etc. These materials were collected in farmyard manure (FYM) pits, composted, and spread over the fields. Charcoal, a byproduct of traditional stoves, is added to the FYM or compost pits, inoculated naturally with soil microbes, and later taken to the field and applied to the soil.

Traditionally, in the absence of pesticides and chemical fertilizers, native soil microbes and other life forms flourished. Very little soil life exists now.

Biochar is a recent term, but application of charcoal to the soil in conjunction with other additives is a practice as old as civilizations. Terra Preta in the Amazon, Raab in India, Babito in Cameroon, and Bokashi in Japan are some examples.

Biochar is considered by some as an immediate solution for soil fertility management, whereas Terra Preta is a cultural practice and a long-term solution.

Challenges

Exponential population growth, soil degradation and hardening, alkalinity, water scarcity, depletion of agricultural resources, food security, climate change, and global warming are serious concerns.

Current unsustainable practices are enhancing the vulnerability of communities and are detrimental to the fragile ecology and the environment. Biocharculture is a means to integrate traditional and cultural practices with current practices for sustainable livelihoods and to find solutions to the many present and future challenges faced by the planet.

Climate change - variability / extremes

Soil fertility

Water management

Impact of hazardous pesticides and nitrogen fertilizers

Burning of crop residue

Alkalinity of soils

Picture 10 Challenges in agriculture are diverse and severe

Sustainable agriculture

Picture 11 Today the livelihoods of small and marginal farmers is at stake due to unsustainable agricultural practices

In the name of development and green revolutions, modern agriculture has introduced unsustainable practices much to the detriment of agriculture, soil, and the local environment. Farmers who were once independent are now very much dependent on inputs like quality seeds, subsidized fertilizers, minimum support price of their produce and access to finance from institutions.

Modern agricultural practices are also criticized for releasing GHGs from soils, such as Methane (CH_4) emissions from paddy fields and Carbon Dioxide (CO_2) emissions from the burning of crop residues. Also criticized are practices such as the tillage of lands with farm machinery that produces harmful emissions, emissions released from ploughed lands, the consumption of excess energy during agricultural operations, and Nitrogen Oxides (NOx) emissions from the use of fertilizers.

Mechanization and improper farming practices have led to soil erosion and degradation. For example, according to the Government of India, about 146 million hectares of land in the country are considered degraded. Farmers still believe that applying chemicals is good for soil. Nevertheless, agricultural productivity is declining.

Currently, two of the biggest challenges in agriculture are to achieve food security and to mitigate global warming. There is a need to increase nutrient density in food as well as to grow more food from limited, depleting resources. Along with climate change, climate variability and extremes are affecting crop production and increasing crops' vulnerability to pests and disease. With significant reduction in organic amendments and unscrupulous application of chemical fertilizers and pesticides, soils have been literally poisoned.

In addition to land degradation, extreme alkalinity and salinity of soils is another human-induced problem. The depleting of water resources and soil moisture affects crop survival and growth. The mismanagement of biomass is a major problem. Multi-story apartments have been built in urban areas to support dense populations. A similar tactic should be used for soil—space should be created to maximize the survival and density of soil microbes. In this regard, there is a need to improve soil environments, remove hazardous elements from soil, and improve the availability of nutrients and minerals to increase crop production and improve the quality of the produce. Current agricultural practices are non-sustainable and cannot meet these goals.

In the past, domestic livestock has supported agricultural systems as sources of energy, fertilizers, and many other byproducts. Livestock is now depleting and farm-animals are being replaced by machines. The depleting supply of fodder waste and animal dung and urine should be conserved for effective use. The overall environment and health of animals should be improved. Biochar is a solution with the potential to add value to the management of all of the above aspects.

Picture 12 The biochar soaked in animals urine and air-dried is an excellent resource for application to soil

The hypothesis is that if Terra Preta soils occurred in the Amazon basin, there is no reason why other civilizations around the world would not have discovered similar properties of charcoal or cannot adopt them today!!

Climate change mitigation

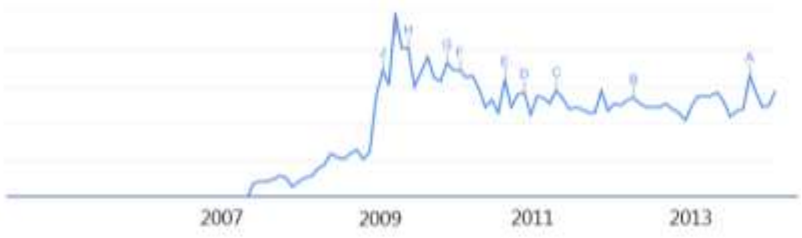
Picture 13 Biochar is a useful for reclaiming degraded soils

Biochar is more recalcitrant than organic matter, therefore it resides in the soil for much longer than other organic materials—well over 1,000 years. Because of its longer life, biochar is useful to apply to soil for carbon sequestration. Laboratory studies using the latest technology estimate that biochar has a mean residence time in soil to the order of 1,300–4,000 years (Cheng et al., 2008; Liang et al., 2008). Biochar can store carbon for centuries and even millennia (Lehmann, 2007 in Hansen, 2008).

Application of biochar decreases N_2O, CH_4, and CO_2 emissions from the soil through absorption and adsorbtion, reducing GHG emissions. NO_x emissions have been known to decrease by up to 80%, and CH_4 has been known to be completely suppressed through the use of biochar (Rondon et al., 2005 in Lehmann, 2007 and Gaunt and Lehmann, 2008.) The biochar application method is useful for the reduction of GHGs in paddy fields, FYMs, and composts.

Biochar trends

The term ‘biochar’ has achieved popular use since 2007, as the statistics below from Google Trends reveal[2].



Picture 14 There is a growing trend and interest in biochar globally

As per LinkedIn statistics, biochar is becoming increasingly important, with 19% growth per year in profiles listing biochar as a skill. Biochar represents the primary industry Renewables & Environment.

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[2] Google Trends - Web Search interest: “biochar”-Worldwide, 2004 present http://www.google.com/trends/explore?hl=en-US&q=biochar&cmpt=q&content=1 #googletrendsexplore

Table 1 The following countries have agencies, organizations, individuals, etc. expressing interest in biochar

Country	Percentage	Country	Percentage
Australia	100	United Kingdom	29
Canada	49	India	22
United States	41	Italy	22

Table 2 The following terms associated with biochar and their importance have been searched

Related searches	Percentage	Related searches	Percentage
biochar soil	100	biochar pyrolysis	45
biochar production	65	biochar stove	45
pyrolysis	50	international biochar	45

Value of biochar in India

The application of biochar to soils has been practiced since prehistoric times. However, biochar's use was not explicit; for a long time, it continued as a traditional best practice in India and many other parts of the world. These traditional practices are wide-ranging, most notably in agriculture. Perhaps soils in India remained fertile due to several other good practices as well, so there was not much necessity to apply biochar in large quantities. Nevertheless, biochar was never considered a waste material.

There are many sources of biochar:

Crop residue and weeds burnt in the fields are converted into biochar and ash. This practice has benefited soils and farmers for ages.

Charcoal (biochar), a byproduct that comes from traditional stoves, is also added to FYM. The biochar gets inoculated with the soil microbes, which is later transferred to the fields. Waste from potters' kilns is a combination of charcoal, pottery shards, and ash. This has always been a valuable source for improving soil fertility.

As additional evidence comes to light, it becomes clear that Indian farmers have been using biochar for hundreds of years. In many parts of India, agriculture is still a sustainable practice, largely on account of such good practices adopted.

Author’s journey into biochar

In visits to parts of India for studies and evaluations, the author has come across several challenges to soils and agriculture. The observed reality has sensitized and motivated him to work on soil management for agricultural sustainability, food security, and livelihoods. It has been nine years since he began his endeavour to understand the value of biochar amendments to soils and other applications of biochar.

The author’s studies were conducted mainly among farmers in semi-arid areas in parts of Telangana, India. In this region, low and erratic rains have led to frequent droughts and reduced the crop yields. As a result, the livelihoods of villagers’ primarily dependant on the agriculture are at stake. Vegetation in the region can be described as ‘tropical dry deciduous, with small trees interspersed through scrub vegetation. Agriculture is the main livelihood activity, and is heavily dependent on rainfall. The soils are diverse, including sandy soils, red soils, black cotton soils and alkaline soils, and support a variety of crops. Common crops include paddy, sorghum, maize, sesame, red gram, green gram, cotton, chilli, vegetables, and horticultural crops such as mango.

Biomass cook stoves are one of the sources of biochar. In Telangana, many people still use traditional clay and three stone stoves. Some produce charcoal from *Prosopis Juliflora* and local biomass using traditional earth mound kilns, creating pressure on scant biomass resources. Part of the biomass from land development activities is disposed of by open burning. This results in biomass loss, air pollution, and wasted energy. Cotton is one of the major crops cultivated. After harvest, many farmers openly burn the remaining cotton stalks in the fields, generating smoke and ash. Very little biochar is formed in the open burning process. On the other hand, demand for charcoal has been increasing. To fill the gap, the local population has been converting locally available biomass into charcoal through traditional methods.

To support communities reliant on biochar and related aspects, the author has engaged in a number of activities.

- Study, design and introduction of energy efficient and clean burning cook stoves that produce biochar as a by-product
- Development of appropriate biochar amendments for increased soil fertility and crop yields
- Introduction of improved charcoal production techniques from *Prosopis Juliflora*, pine needles, cotton stalks and other biomass.
- Introduction of crop residue conversion into biochar as an additional livelihood opportunity for farmers.

These efforts aim to demonstrate climate change mitigation practices at the micro-level carried out by communities. The scope of biochar has expanded during interactions with communities. Field trials, experiments, and capacity development programs conducted in various parts of India have aided the discovery of traditional practices and methods of biochar use. The author has discovered the value of biochar for multiple purposes, describing them collectively as “biocharculture.” He has helped to create wider awareness of biocharculture and promoted policy dialogues on sustainable agricultural practices at various levels.

The author has conducted a number of biochar experiments, initially on rooftops. To continue pursuing his research interests on biocharculture, he established the GEO Research Centre in Peddamaduru village, Devaruppala Mandal, Warangal District, Telangana, India (17°36'1.92"N and 79°18'2.74"E). This location is about 100 km northeast of the city of Hyderabad. Also called the 'Geo Spirit Centre', the research centre carries out biochar production and processing and houses a wide biodiversity, with over of 200 plant species and related soil microbes on half an acre of land. The centre also produces biochar bricks used in the construction of 'green buildings.' The centre also has a 'Stoves Museum,' with gasifier stoves that produce biochar.

The author developed the concept of "Geo Spirit Centres" to encourage conservation and facilitation of local biodiversity, especially soil microbes.

They are "sacred spaces," as declared by communities. Such sacred spaces include specifically identified 'ancient' forests and other "natural landscapes" that are intended to be preserved, not only for the "mental health" of the people, but also (literally) to protect and preserve the Soil diversity and health -- and, thus create a "legacy" that ensures both Food and Bodily health -- the 'body' of the Earth itself -- is held sacred.

Geo Spirit is defined as spirit of the earth. These sacred spaces can be declared as Geo Spirit Centres, where people care for and come to respect "Mother Earth". In the literal sense that the word "Earth" is also a synonym for the SOIL -- which means that literally, they are places to protect, respect and care for "Mother Earth", which literally could mean respect and care for the "Mother Soil". It is true that the soil is really our "Mother" ~ for without healthy soils, NO LIFE (on land) would exist. The earth is a single living thing, which represents oneness and diversity.

And once we have created these "Mother Soil" sanctuaries -- the "Spirit Centres" where soil (microbial) biodiversity is encouraged and left to flourish... we may then get an opportunity to use tools like biochar compost that has been inoculated by the "Mother Soils", to help restore our badly degraded lands.

In this case, heat sterilised biochar could be considered the "carrier" of soil biodiversity, allowing the abundant microbes from the 'Mother soil' transferred as intact as is possible, from the point of origin [the 'Sacred Spaces'], and be placed onto degraded lands, to act as the seed that can then re-populate these essential microbial communities back in the degraded landscapes. At a time when microbial biodiversity is suffering great losses and affecting soil health, these centres could serve as storehouses for microbes, which could be inoculated into the local soils by farmers using biochar.

The communities are motivated to set up such Geo Spirit centres. In these centres, GEO Spirit meetings are conducted for “Earth Leaders”. Earth leaders are all those who contribute for the sustainability of the earth.

GEO SPIRIT centres strive for the following principles:

- Being sensitive
- Self realization
- Interconnectedness
- Love for all
- Striving for change
- Understanding - one for all and all for one
- Integration of good learning's
- Striving for Good Earth System Governance
- Spirit of open knowledge
- Integrity and
- Freedom

> *The philosophy of biochar has led me to understand it in the context of science, culture, society, economy, tradition, art, and history. It is a panacea, and much more …*

Traditional biochar sources

☐ Traditional use of biochar; biochar sources and practices; pottery shards use along with biochar.

Traditionally, biochar has been used in many parts of the world. In the context of global warming, food security, reclaiming degraded soils, enhancing soil productivity, reducing soil leaching, and sequestering carbon, etc., biochar has regained prominence.

Ancient civilizations understood biochar's use in improving soil fertility for agriculture. Improving soil fertility to improve food security has been a major concern of farmers for several centuries, as it affects their livelihoods.

On an average, 30 to 50 kilograms of biochar can be produced by inefficient production methods that involve collecting biomass from an acre of land after harvesting the produce. Crop residue is otherwise burnt openly by some farmers, which is not recommended. About 100 to 250 kilograms of biochar could be produced per acre through controlled and efficient pyrolysis in fields from the average amount of crop residue left over every season. Considering that the life of biochar found in the soil in agricultural fields is about 1,000 years, burning biomass would effect a cumulative accumulation of biochar (irrespective of how little is produced after each burning). A majority of fields currently under cultivation are at least 100 to 200 years old. This means that there are at least 10 tonnes of biochar in their soils, accumulated cumulatively over time. Application of biochar to fields should be preceded by a measurement of the pre-existing biochar in the soil and other substances such as pottery shards and bones.

In discussions with farmers on why they prefer to burn biomass in the fields, they said that it is easy to carry out farm operations like weeding and ploughing without interference from the biomass stumps. Burning of biomass results in baking of the soil, which kills certain dormant larvae that could otherwise develop and cause damage to crops. Burning also reduces the presence of termites and ants. However, it is also quite possible that beneficial life forms also die in the process.

People burn millions of tonnes of crop residue in several parts of India, especially from January to July, as part of preparing the field for cultivation. The burnt residue gets converted into biochar and ash. This practice has benefited soils and farmers for ages.

Burning of biomass in forest fires and burning of open crop residue produces smoke and aerosol particles that are considered a major source of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4), volatile organic compounds (VOC), nitrogen oxides, and halogen compounds. The GHGs CO_2 and CH_4 directly contribute to global warming.

Traditionally farmers were independent; over the years they are made dependent

Rural trash

Picture 15 Pieces of biochar as found in a rural trash

Traditionally, rural trash consisting of dung, urine, straw, bones, pottery shards, biochar and ash etc., was used to make FYM. In rural areas, trash is collected from various sources, such as livestock sheds (dung/excreta, fodder waste, urine soaked waste fodder), houses (grime and wastewater left over after cleaning floors, broken tiles), stoves (biochar and ash), and kitchen waste (food scraps, vegetables, bones, broken pottery). As part of the process to produce FYM, this trash is routinely dumped in a pit for up to a period of one year. FYM is an excellent source of soil microbes and organic nutrients with which to inoculate biochar to enhance its properties. Pottery shards also enhance the fertilizing capabilities of compost. This is just one example of the extent to which biochar is integrated in traditional systems of soil fertility management.

Very little biochar is used in the method described above, and most of it is derived from stove residues. This is a traditional practice in many parts of the world. It is in view of this practice that livestock is often kept close to the residential areas. Compost pits located away from residential areas may not have any biochar in them.

Traditions

Bonfires for religious ceremonies, cultural activities, festivals, holy altars, cremations, etc. also leave behind biochar and ash. During major festivals in India, like *Holi* (the festival of colours), *Sankranti* (post-harvest festival), and *Deepawali* (the festival of lights), large quantities of biomass are burnt. The resultant residues and byproducts also eventually reach the soils.

In India, farmers still favour biochar and ash sourced from cook stoves, burnt crop residue, and charcoal and ash from *Yagnas* (a

Bonalu Festival

The Bonalu festival is celebrated immediately after the first rains in parts of Telangana State, India, in which the goddess Mahankali or Yellamma is worshipped. Worshipers sacrifice animals (sheep, goats and chicken) before the goddess and leave offerings, including cooked rice with milk and jaggery in a new earthern pot, adorned with neem leaves, turmeric, vermilion, water, toddy, lamps made of rice or wheat flour, and coconuts. Many new pots are also used. The blood of animals and the other materials offered is left on the floor before the goddesses for one day. This material together is called Prasadam. The next day, the prasadam is taken in a procession and spread in and around fields and water bodies. This festival is significant, because the prasadam helps to spread good soil microbes, contributing to the prevention of disease and prosperity for local communities. If the prasadam is applied to the fields with biochar, it renders more value as a whole.

ritual performed for prosperity), potters kilns, etc. They apply silt from irrigation tanks and FYM, which are traditional practices. All these practices increase soil carbon, microbial activity, and fertility.

Sometimes, to ward off evil spirits, people write "to come tomorrow" with charcoal pieces, as each day has a new tomorrow, meaning that evil will never come. Biochar is also believed to ward off 'ghosts.' So-called ghost usually manifest in anaerobic environmental conditions, which is nothing but bad air. Biochar absorbs bad air. A traditional death ritual in parts of rural India is to collect ash, charcoal, and charcoal bones after cremation to immerse them into the streams or rivers.

Biochar mitigates many negative effects on the environment and creates a better space for life on earth. The gods too had a similar intention for life on earth. The story of Lord Shiva can be taken as an example to understand biochar, as Shiva symbolizes rhythm and harmony. It is said that to save life on Earth, Shiva once consumed poison and stored it in his throat. Similarly, biochar now takes the 'poison' from Earth and provides a chance for life. If Lord Shiva opens his third eye, everything will be destroyed and will turn into *vibuthi* (sacred ash). If biochar burns, only ash remains. Shiva decorates his whole body with ash. Snakes love charcoal, so there is always a snake around his throat. The River *Ganga* (India's sacred river) is on his head. Charcoal has the tendency to hold soil moisture. Thus, many properties of biochar can be symbolized by Lord Shiva.

Ash is the leftover material after all the energy from charcoal is lost; it is considered the sacred symbol of emptiness.

Potters Kilns

Picture 16 Traditional potters kiln source of biochar, ash, pottery shards and burnt soil

Residual material from traditional potters' kilns is a good additive for the soils. The association between charcoal and pottery shards is a longstanding tradition. During the production of pottery in the kiln or retort, the baking process is slow. In the kiln, the biomass used as fuel gets converted into biochar and ash, broken pottery, and biochar are left behind. This mix of byproducts improves the soil condition when applied. Farmers and traditional potters know this quite well, considering the byproducts 'gold' for soil.

Residues from potters kilns include:

- Charcoal - mostly from the wood used
- Ash - from the straw and wood used
- Broken pieces of pots (some pots break during the baking process)
- Burnt soil (used to cover the kiln)

Together, the above components result in a good additive for acidic soils. Potters rarely share them with others; they prefer to use them in their own fields.

Pottery Shards

Picture 17 Very old pottery shards collected from an agricultural field

Shards of broken pottery are commonly found in the village life of most cultures. Like biochar, pottery shards have multiple uses, eventually reaching agricultural fields and soils in rural areas. The remains from potters kilns—a combination of charcoal, pottery shards, and a little ash—have always been a valuable resource for improving soil fertility. Although the addition of charcoal to soils has long been practiced, it was not widespread and remained only a traditional practice in India. Because of such good practices, agricultural activity is still sustainable in many parts of India.

Wherever agriculture was the main livelihood, high densities of population existed. When civilization was at its peak and space was a constraint, human beings came up with innovative practices that have proved to be sustainable until today. Charcoal, ash, and pottery shards are the most common byproducts of human habitats. Their use / reuse are an example of innovative practices that emerged out of lack of space and resources.

Invariably, some amount of biochar and ash was produced by the customary activities of people living in traditional settlements in the past (see table above). At this point, there are many parts of the world where the availability of such byproducts in sufficient quantities, and their ingenious use and management remain under development.

Table 3 Sources of biochar and pottery shards from parts of rural India.

Activity	**Biochar**	**Pottery shards / Baked earth**
Cooking	Yes	Pottery shards
Water Purification	Activated carbon after use	Pots used for storing water - pottery shards
Slash and burn	Yes	Baked earth
Crop residue burning	Yes	Baked earth
Forest fires	Yes	Baked earth
Potters kiln	Yes	Pottery shards
Community kitchens (Hotels / Schools / temples / etc.)	Yes	Pottery shards
Ceremonial pottery used for all cultural occasions		Pottery shards
Religious - Holy altars / *Yagnas / Agnihotras*	Yes	Pottery shards
Cultural Bonfires	Yes	Pottery shards
Cremation grounds	Yes	Pottery shards
Housing		Roof tile shards during replacement

Baked clay pottery is quite popular, with millions of pieces still produced and used in India. A large number of the rural poor cook food in clay pots. Pots are also commonly used to collect and store drinking water, with usage increasing in the summer. Water evaporation from the fine pores of these pots cools the water inside it. The temperature is at least five degrees centigrade cooler than the surrounding air temperature. The cooling effect is especially high under relatively less humid conditions. Roofs made of clay tiles also provide cool shelter, and are very useful in the tropics where temperatures are very high during the summer months. For almost all types of festivals, events, and occasions pottery is used in the rituals. In many parts of India, pottery is continually in use. For all these reasons, large quantities of pottery shards regularly contribute to rural trash, which eventually finds its way into soil.

Picture 18 Shards of disposable pottery tea cups

Picture 19 The broken pottery roof tiles

The clay from local water bodies (tanks, ponds, lakes, rivers, etc.) is used for making pottery. The organic carbon content in this clay is around 0.9%. Such clay is mixed with ash, charcoal powder from the kilns, and sometimes sand (quartz) is also used. The availability of water bodies determines access to clay and sand for pottery.

Pieces of broken pots are usually disposed of in farmyard manure pits. As the manure is applied and spread over the fields, the pottery shards are also spread. With time, the size of the pottery shards reduces due to breaking. Eventually and over several years, the pottery shards spread out more widely. The density of occurrence of pottery shards varies from field to field.

Historically, the use of biochar was mostly a cultural or traditional practice. However, the Japanese still use bamboo charcoal in many ways. Biochar is not a new invention, but there is a need to re-discover its use and evolve new uses.

Once applied to the soil, biochar gets saturated and serves the purpose of carbon sequestration. The saturated biochar may or may not actively host soil microbes.

Characteristics of biochar

On Characteristics of biochar; hydrophobicity and oxidation; understanding carbon; and size of biochar

Biochar is a process medium rather than a 'result' medium. However, testing the chemical composition of biochar as a ‘result’ medium is easier than estimating and appreciating the real value of the functions biochar performs in space and over time. For example, evaluation of a process medium could involve measuring the moisture retention in the soil, the extent of aeration of the soil, the level of absorption of harmful pesticides and chemicals from the soil, speed of the release of nitrogen into the soil, level of absorption of GHGs from the soil, temperature regulation in the soil, and quality of habitat for the thriving of soil microbes, among other variables.

To understand biochar, one needs to conduct an experiment. Take four pieces of land with the following compositions: a) soil and biochar; b) soil, biochar, and amendments; c) soil and amendments; and d) control soil. Sow seeds on each piece of land and monitor the following: germination, height of plants, number of leaves, and development of flowers and fruits at regular intervals. These observations will be more meaningful than testing the chemical composition of the soil, because it is the characteristics of biochar that matters in gauging its value.

Hydrophobicity

Over a period of time biochar loses its hydrophobicity due to oxidation. Initially, the fresh biochar floats in water. After a few days of treatment with water or moisture it attains maturity and starts absorbing water. It is observed in the field that the coolness attributed to the presence of moisture in biochar attracts creatures such as scorpions, snakes etc., to take shelter near or under its mass. .

Picture 20 Author explaining the hydrophobicity nature and other characteristics of biochar

Biochar is neither a nutrient nor food for soil microbes but rather a catalyst for the soil.

Carbon

An argument is often put forward that biomass in all its different forms should be returned to the soil. However, the benefits of compost and biochar are not the same, even though both are derived from the same biomass. Compost is food for soil life and a source of nutrients and minerals for plants. The benefits of compost last just for a few years, whereas the benefits of biochar last more than 1,000 years and also enhance the value and benefits of the compost exponentially.

One hectare is 10,000 sq. meters. If a hectare of soil is 33.5 cm deep with a bulk density of 1.4 tonnes per cubic meter, soil mass per hectare is about 4,700 tons. If appropriate management practices were adopted and these practices achieved and sustained, there would be a 1% increase in soil organic matter (SOM), working out to about 47 tonnes of SOM per hectare being added to organic matter stocks held below the soil surface. These 47 tonnes of SOM contain approximately 27 tonnes of soil carbon (i.e. 58%) per hectare. In the absence of other inputs soil carbon may only be derived from the

Importance of carbon

Life on the earth is mainly carbon-based. The manifestations of carbon in different forms and properties are most useful when present in balanced quantities and proportions. The greenhouse effect is mainly a result of the increase in carbon dioxide, which is carbon and oxygen. As explained in this book, there are also solutions based on biochar, which is also a carbon form.

atmosphere via the natural function known as photosynthesis. To place approximately 27 tonnes of Soil Carbon per hectare into the soil, around 100 tonnes of carbon dioxide is consumed out of the atmosphere by photosynthesis. Therefore, a 1% change in SOM across 5 billion hectares will sequester 500 billion tonnes of physical carbon dioxide[3].

Every 1% increase in retained SOM within the topmost 33.5 cm of the soil would capture and hold approximately 100 tonnes of atmospheric carbon dioxide per hectare (the variability in the equation being due only to soil bulk density)[4]. For each 1% increase in SOM achieved on the 5 billion hectares, 64 ppm of carbon dioxide will be removed from atmospheric circulation (500,000,000,000 tonnes carbon dioxide / 7,800,000,000 tonnes carbon dioxide = 64 ppm.).

One tonne of carbon dioxide contains 12/44 units of carbon (i.e., 0.27 tonnes of carbon per tonne of carbon dioxide). Therefore, 27 tonnes of carbon sequesters 27/0.27 = 100 tonnes carbon dioxide

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[3] Soil Organic Matter is the plant material released into the soil during the natural phases of plant growth. It includes root material ploughed off below the soil surface and plant Litter carried into the soil by microbes, insects, and rainfall. Soil Carbon is the elemental carbon contained within Soil Organic Matter (SOM).

[4] Tony Lovell of Soil Carbon P/L in Australia estimates that by actively supporting regrowth of vegetation in damaged ecosystems, billions of tons of carbon dioxide can be sequestered from the atmosphere. http://news.mongabay.com/2008/0221-soil_carbon_lovell_interview.html

(rounded off). Carbon atomic weight = 12, Oxygen atomic weight = 16 . Therefore, molecular weight of carbon dioxide =12+(16+16)=44.

As more compost and mulch along with biochar are added, the activity of microbes residing in the charcoal increases. The microbes use the SOM as food. Overall, the carbon content of the soil improves due to the biochar and increased soil microbial density.

Lehmann et al. (2006) estimate that a total of 9.5 billion tonnes of carbon could potentially be stored in soils by the year 2100 using a wide variety of biochar application programs. Once equipped with a better understanding of this potential synergism and the mechanisms that drive it, biochar could be used to sequester carbon in soils, thus contributing to climate change mitigation. This interaction could also be harnessed for the restoration of disturbed ecosystems, reclamation of sites contaminated by industrial pollution and mine wastes, increasing fertilizer use efficiencies (with all associated economic and environmental benefits), and development of methods for attaining increased crop yields from sustainable agricultural activities.

Carbon is important for soil, especially soil carbon. Another important carbon is biochar, applied as a soil amendment.

Size of biochar

Traditionally, the amount of biochar added to the soils has been incremental, with small amounts of biochar from stoves and other sources finding their way into the soil. Different grades (sizes) of biochar are found in the soil, serving different purposes in the field. The benefits of biochar to soil depend on various aspects, like physical, chemical, biological and electromagnetic environments.

Over a period of time, larger chunks have broken down into smaller pieces. The finer the biochar, the farther it can be spread over a larger area for immediate results. In any case, over a period of time the biochar located up to a depth of 8 to 12 inches breaks during land tillage and other farm activities. Using chunks of biochar has the following advantages:

- Roots prosper around chunks.
- Soil moisture evaporates from a fine speck of biochar much more easily than from a larger piece.
- Soil microbes and soil fungus can find a convenient habitat within a chunk of biochar. Whole communities of these micro organisms can live within a single chunk.
- Heavy pieces are less likely to get carried away from the field by wind or water.
- Much more air circulation is possible around a chunk of biochar.
- Using pieces saves the additional energy required to powder them.
- Larger pieces have greater insulation capacity to regulate temperature of soil.

Biomass sources for biochar

On sources of biomass for biochar; and stoves as a source for biochar

Biomass from crop residue, weeds, surplus biomass, grasses, excess forest litter, animal manures, municipal waste, etc., can be used for conversion into biochar. Therefore, the process is a means for managing waste. Efficient biochar production prevents wasteful burning of millions of tonnes of post-harvest biomass in open fields and the resultant emissions. A majority of small and marginal farmers can easily adopt efficient biochar production technologies using the biomass available in their fields and surroundings.

Picture 21 Biochar from various sources of biomas

Sludge from sewage could also be safely converted into biochar, provided that it is tested for harmful elements. The resultant biochar can be used to reduce emissions from sewerage and water treatment systems.

Lal (2005) estimates the world production of crop residues to be 4x109 Mg/yr. Taking the mean carbon content to be 48% and a pyrolysis yield of 48% of this carbon in the char (Lehmann et al.,

Picture 22 Prosopis Juliflora an exotic species in many parts of the world, grows luxuriently

2006), A maximum of 1 PgCyr-1 biochar could be produced from agricultural residues if all current global agricultural residues were converted to biochar. In practice, this figure will be constrained by cost, suitability of different residues, requirements to incorporate residues into the soil, and other competing demands. How much biochar might be produced from agricultural residues once such constraints have been taken into account is a question that requires further research.[5]

Prosopis Juliflora biochar waste, it is a combination of fine charcoal mixed with burnt earth, which can be sourced from local charcoal kilns. Rice husk biochar can be found in local parboiled rice mills, which is a byproduct of using rice husk as fuel for the boilers. Exotic and invasive species of plants, residue from crops that are otherwise burnt in the open, energy plantations, and timber waste are other examples of the numerous sources of biochar.

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[5] http://orgprints.org/13268/1/Biochar_as_a_soil_amendment_-_a_review.pdf

Picture 23 Some part of forest litter is a very good resource for biochar and one of the solutions for preventing forest fires

Prosopis Juliflora is an exotic species in India and grows profusely in all conditions. It is a major source of biomass available from fallow lands. *Prosopis Juliflora* grows luxuriantly in the alkaline soils too. The biochar generated from the plant material has both commercial value as charcoal, and is used in biochar compost. Utilizing such resources minimizes impact on the environment and deforestation. Such sources of biomass exist in every region; they should be identified and used.

Biomass sourced from the agriculture sector in India is about 800 million tons. Of that total biomass, at least 20 to 30 percent is wasted. Burning crop residue in the fields is a common phenomenon as a preparatory measure before sowing a new crop. The percentage of crop residue burnt varies from place to place and from crop to crop. Here are the six major crops cultivated in India and the quantity of crop residue they leave behind in million tonnes: Rice (13.1), Wheat (15.4), Sugar (21.6), Groundnut (3.3), Mustard (4.5), and Cotton (11.8)– totalling about 69.9 million tones.

Crop residue is converted into compost or manure, but mostly ends up being burnt and turned into ash. Ash is valuable, especially in acidic soils, for its phosphorous and other mineral content.

Considering the value of biochar especially in poor, degraded soils, there is a need for technologies to efficiently convert biomass into biochar. Crop residues like those of cotton plants are hard and could yield good biochar, but handling it and converting it into biochar consumes a lot of labour and energy.

The energy produced during the process of converting biomass into biochar should also be used for some practical applications. Many farmers simply burn crop residue in their fields wasting the energy. However, thermal power plants based on biomass are emerging. This industry generates ash as its byproduct. These thermal plants compete with the biochar production plants for biomass.

The crops being currently grown are improved or high yielding varieties or short duration crops, which have less biomass compared to traditional crops. The overall biomass available as crop residue has been diminishing over the years. In this context, there is much need to create large-scale awareness among farmers about the importance of converting biomass into biochar wherever possible.

In a typical semi-arid village in certain parts of India, biochar comes from the following sources: *Prosopis Juliflora* biochar waste from local charcoal kilns; Rice husk biochar from parboiled rice mills, as a byproduct of using rice husk as fuel for the boilers; biochar produced from crop residues; and biochar from biomass cookstoves.

Biochar is to the soil what coral reefs are to the sea.

Stoves

Biomass has been in use for cooking needs since prehistoric times. Even today, the majority of the rural population is partially or completely dependent on biomass stoves. Worldwide, more than two billion people today cook on traditional stoves and open fire using fuelwood, crop residues, animal dung cakes, and other biomass as fuel.

Picture 24 Biochar a by product from cook stoves is dumped in a farm yard manure pit

Charcoal from stoves is one of the sources of biochar. Stoves that can use crop residues as a fuel source can also address the problem of sustainable disposal and use of biomass.

The author has designed more than 25 top lit updraft or gasifier stoves, including natural draft and forced draft stoves. On an average, these stoves yield fourteen percent biochar of the total quantity of wood used. Cooks should recover the biochar left after cooking by removing charcoal from the stove and quenching it with water. The actual recovery of biochar in a cook stove depends on the practice adopted, the stove design and the willingness of the cook.

Magh 3G stove 14%

Magh 3G stove steel 19%

My Home Stove 16%

Magh CM Stove 19%

Picture 25 Biochar weight in percentage of the quantity of wood used as fuel

The range of biochar yield is from 14% to 19% in the above gasifier stoves. In comparison, the typical total yield of around 6% to 8% from three-stone stoves is too low to be considered a source for biochar.

> *The main challenges are the availability of sustainable sources of biomass and accessibility of efficient biomass-to-biochar conversion technologies.*

Biochar production

Biochar production systems should recover and use all the energy output with minimal waste and use byproducts such as wood vinegar, ash, etc.

On biochar production as practices; slash and burn; crop residue and other biomass

Table 4 Elemental composition and atomic ratios of biochars produced from different feedstocks and at different pyrolysis temperatures.[6]

Feed-stock	Pyrolysis Temp. (^{0}C)	Elemental composition (%, oven-dry wt. basis)								Atomic ratios		
		Ash	C	H	O	N	S	Na	P	H/C	O/C	(O+N)/C
Peanut hull	0	3.3	50.7	6.1	38.1	1.7	0.09	_	_	1.43	0.56	0.59
	400	8.2	74.8	4.5	9.7	2.7	0.09	<0.01	0.26	0.72	0.01	0.13
	500	9.3	81.8	2.9	3.3	2.7	0.1	<0.01	0.26	0.42	0.03	0.06
Poultry litter	0	24.4	36.2	4.8	24.4	4.1	0.32	_	_	1.58	0.51	0.6
	350	35.9	46.1	3.7	8.6	4.9	0.78	1.88	2.94	0.96	0.14	0.23
	700	52.4	44	0.3	<0.01	2.8	1	2.69	4.28	0.08	<0.01	0.06
Switch grass	0	2.3	48.3	6.2	42.7	0.51	0.05	_	_	1.53	0.66	0.67
	250	2.6	55.3	6	35.6	0.43	0.05	<0.01	0.1	1.29	0.48	0.49
	500	7.8	84.4	2.4	4.3	1.07	0.06	0.01	0.24	0.39	0.04	0.05

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[6] Characterization of designer biochar produced at different temperatures and their effects on a loamy sand, Jeffrey M. Novak[1]*, Isabel Lima[2], Baoshan Xing[3], Julia W. Gaskin4, Christoph Steiner4, K.C. Das4, Mohamed Ahmedna5, Djaafar Rehrah5, Donald W. Watts[1], Warren J.Busscher[1] and Harry Schomberg6 *JM Novak et al., Annals of Environmental Science / 2009, Vol 3, 195-206*

Most of the charcoal produced in developing countries is produced in earthen kilns and the biomass to biochar conversion factor can vary from about $10m^3$ per tonne of charcoal to $27m^3$ per tonne depending on the moisture content, type of the biomass and the skill of the operator.

Efforts to develop sources of biochar should include focusing on establishing supply chains of highly-efficient biochar-making cookstoves. It is important to encourage the pyrolysis of agricultural residues through the diffusion of improved small-scale biochar kilns or retorts.

Diamonds and biochar: Although both are basically carbon, biochar is more valuable for the multiple functions it performs.

Slash and burn

Picture 26 A typical burnt grassland

Slash-and-burn agriculture practiced at the margins or inside forests is common in many parts of the world. In the process of slash and burn agriculture some biochar and ash is formed as a byproduct. As the population has grown, the demand for land has increased. There is already stress on forests due to increasing encroachments upon forests and policies of various governments giving away forest lands for agriculture or lumbering purposes. The traditional practices like slash-and-burn are no longer sustainable. Were they to continue, entire forests would disappear.

Every civilization would use all the best material available locally for their livelihoods.

Why do farmers burn?

Picture 27 A farmer burning crop residue

A bumper crop can leave a tremendous amount of straw, which can be very difficult to work into the soil or spread evenly across the field.

Burning is one of the ways to dispose of the straw left after a harvest so fields can be made ready for seeding. A majority of farmers prefer not to burn the residual biomass. They prefer, for example, tilling the straw into the soil by chopping and spreading it out so it does not plug the seeding equipment. However, burning straw is considered a low-cost alternative to ploughing back the straw into the soil. At times, this is the only viable choice left for small farmers. However, burning the residue strips the soil of microbes and moisture that are essential to a crop's long term health.

Burning biomass

Say, India produces 800 million tonnes of agricultural waste and about 200 million tonnes of urban organic waste annually. From 6 major crops like rice, wheat, sugarcane, groundnut, mustard, and cotton, 69.9 million tonnes of crop residue is produced annually in India.

Burning residue releases large amounts of carbon dioxide into the atmosphere—these emissions are ecologically unfriendly. The resultant pollution contributes to global warming. Burning the residue also leaves the soil bare. The soil is then exposed to rainfall and the wind, which can cause erosion and rapid loss of nutrients. The soil then quickly loses its fertility, especially the soil organic carbon needed for sustainable production. Ashes can be disbursed over the soil to improve fertility. However, ashes do not contain the same level of nutrients as the original crop residues and are prone to easily blown or washed away. Burning destroys pests and diseases harbouring in the residues; however, burning also destroys all beneficial organisms in the soil residues!

The use of fire in agriculture is being discouraged across the world as concerns mount about GHGs and air quality. Burning crop residue adds carbon, nitrogen, and hydrocarbons to the air. Fire consumes organic matter and may reduce total nitrogen available for plant growth on the site. Farmers must therefore carefully consider the costs of using fire. In most cases, alternative crop residue management methods make more sense. One such solution is biochar.

Units conversion
PgC/yr - petagram of carbon per year.
1 Petagram (Pg) = 1,000,000,000,000 Kilograms
1 Megagram (Mg) = 1,000 Kilograms

Burning grass

It is common to see burning patches of grass and undergrowth in forested areas. Forest fires result in intentional or accidental production of tonnes of biochar. The soils are enriched in this process. The burning of grass often leads to higher yields of biochar, as there is higher silica percentage in grasses. However, as this process is not controlled it produces relatively less biochar.

Picture 28 The grassland fires are very quick to start and extinguish

Controlled methods should be developed for developing biochar from biomass, and for productively using the heat in the process.

Farmers adaptation

The farmer can plant some of the fast-growing local plants in the field for using the biomass to produce biochar. Farmers can convert the crop residue or use any other less useful plants available in the area for converting into biochar. Biochar can be applied to fields gradually over the next few years. A combination of these practices would be more sustainable and less costly for the farmer.

Importing biochar from elsewhere should not be encouraged, as forests or other natural vegetation could become endangered in regions where it is produced. While it can be argued here that for every tonne of biochar applied to the soil about 3 tonnes of carbon dioxide is sequestrated, one need also account for the carbon dioxide emissions during biochar production and transportation to determine the net impact.

A local source that farmers can use results from the process of charcoal production, as fine charcoal found at the base of each charcoal retort or kiln is of very low value. Farmers can buy this at a very low price from charcoal producers and use it as a soil amendment.

If biochar is not being removed from the soil as fast as it is being produced, it is simply accumulating there, and that itself is desirable!

Local biochar production

Integrating biochar production and application locally is a more sustainable practice than large scale production and dissemination. Commercialization of biochar as a product is a significant concern. At present, no one opposes small and marginal farmers' traditional, sustainable subsistence systems. However, having seen the results of biochar application to sick, poisoned, and dead soils, the demand for biochar products is growing all over the world. There will surely be an increase in demand for biochar products. It is feared that entire forests could be cut down in an effort to produce biochar commercially. Commercial plantations dedicated to biochar production might also emerge, at the cost of food security and local ecology. The impacts would be especially significant if biochar becomes an exported product from poorer to richer countries.

Carbonization of biomass into biochar can have a detrimental effect on the surrounding environment when demand for biomass fuel increases beyond that which can be supplied on a sustainable basis.

To facilitate sustainable biochar production by local communities, they should be helped to organize into societies or cooperatives with the following objectives:

- To form a network of biochar producers
- To adopt improved biochar production technologies
- To add value to biochar by producing biochar compost, biochar fertilizers, etc.
- To market biochar products and blends effectively.

- Liaising with relevant government departments for selling the biochar products
- To optimize the commons facilities for biochar production, including place, water source, shelter, power, etc.
- To plant more plants to maximize availability of biomass for biochar production
- To use some of the wasted biomass for biochar production.
- To insure all the biochar producers and members of society against potential risks during production.

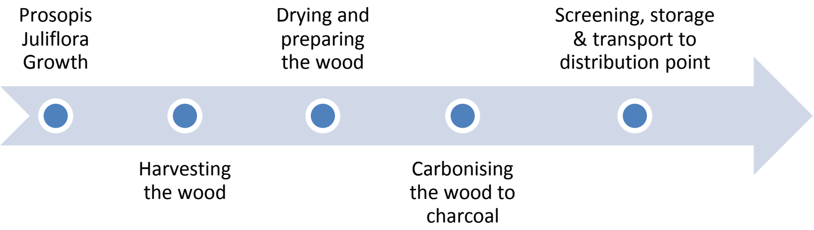
Whether the soils are fertile or infertile, the presence of biochar does them only good.

Biochar production technologies

There are some common methods of charcoal production: earth/brick kilns and metal retorts. The terms kiln and retort are used for a reactor that has the ability to pyrolyse biomass into biochar. Kiln term is used if reactor is made up of bricks and earth (eg., Biochar Kiln) and retort term is used for more controlled reactors made up of say metal (eg., Biochar Retort). Both kiln and retort terms are used if the reactor has the combination of both materials (eg., Biochar retort kiln).

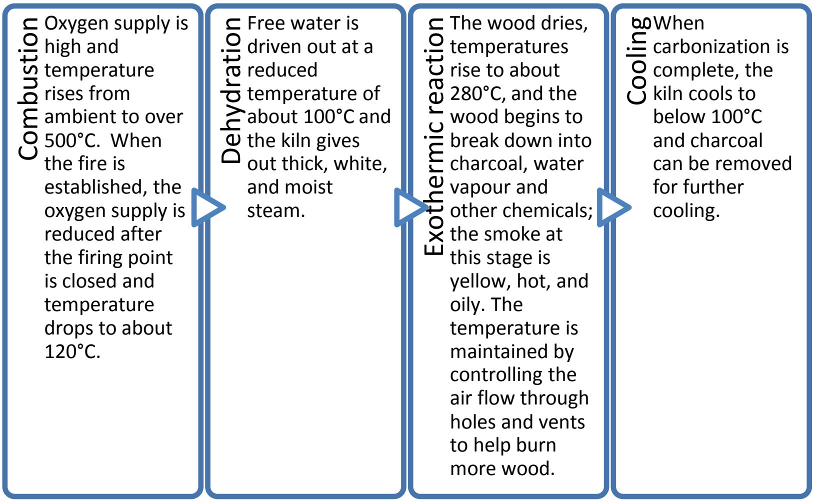
On biochar production technologies; kilns and retorts

Charcoal manufacturing technologies can be classified as either 'batch' or 'continuous multiple hearth kiln' technologies; in both, higher charcoal conversion efficiency and quality can be achieved by controlling the carbonization process properly. During the production of biochar, the energy released should be used for various purposes.



Picture 29 Biochar production process

Traditional charcoal production is an acquired skill. The most critical factor in the efficient conversion of biomass into charcoal is the careful operation of the kiln. Wood must be dried and carefully stacked to allow an even flow of air through the kiln and sufficient time for reactions to take place. If kilns are not operated correctly, yields can drop to below half the optimum level.



Combustion Oxygen supply is high and temperature rises from ambient to over 500°C. When the fire is established, the oxygen supply is reduced after the firing point is closed and temperature drops to about 120°C.

Dehydration Free water is driven out at a reduced temperature of about 100°C and the kiln gives out thick, white, and moist steam.

Exothermic reaction The wood dries, temperatures rise to about 280°C, and the wood begins to break down into charcoal, water vapour and other chemicals; the smoke at this stage is yellow, hot, and oily. The temperature is maintained by controlling the air flow through holes and vents to help burn more wood.

Cooling When carbonization is complete, the kiln cools to below 100°C and charcoal can be removed for further cooling.

Picture 30 A typical charcoal production activity

In the process outlined above:

- Temperature rises from 20°C to 110°C: Wood absorbs heat (energy), and releases water vapour.
- The temperature will remain at or slightly above 100°C until all moisture is driven off (bone-dry).

Picture 31 A farmer harvesting Prosopis Juliflora for conversion into biochar

- Temperature rises from 110°C to 270°C: Wood starts to decompose, releasing gases such as carbon monoxide and carbon dioxide, and liquids such as acetic acid and methanol.
- Temperature rises from 270°C to 290°C: Endothermic reaction commences in the wood.
- Temperatures remain above 270°C. This allows the further breakdown of the wood to occur spontaneously, provided that the wood is not cooled below 270°C.
- Temperature rises from 290°C to 400°C: Further breakdown of the wood allows the release of a number of gases such as carbon monoxide, carbon dioxide, hydrogen, and methane, in addition to condensable vapours such as water, acetic acid, methanol, and acetone. Wood tar begins to predominate as the temperature rises further.
- Temperature levels around 400°C to 600°C: The main process of carbonization is complete, and the charcoal is considered 'soft-burned.' This type of charcoal can contain tar up to 30%, trapped in the internal structure of the material. Further heating drives off more of the tar and increases the fixed carbon content of the final product.

Biochar can be created in many ways. One of the crudest and simplest methods for converting biomass into biochar involves dumping biomass into a trench or a ditch: Burn the biomass, throw more biomass into the burning fire until the heap reduces in size, use soil, water, or use fresh leaf bushes to extinguish the fire. Within 24 hours, some biochar will be available. This crude method is not recommended by the author, as it causes pollution, is less efficient, and is unsafe for the farmer. Conditions such as time of day, temperature, wind, humidity, etc., are important to take into account while producing biochar with this method. Most often, farmers prefer to do this kind of work in the evenings and into the night. This system could be improved so that the pollution is minimal, biochar yield increases, and it is safer for the user.

Eight efficient low-cost charcoal production technologies were designed and introduced to rural communities by the author, designed to convert the crop residue, wood, and other biomass into biochar.

Low efficiency makes charcoal production a principal cause of deforestation in many tropical countries and a contributor to global warming.

Trench mound kilns

Picture 32 A farmer using crop residue in trench mound kiln for biochar production

GEO biochar trench mound kilns are the simplest and convenient method for farmers to convert crop residue or any other biomass on the farm lands into biochar. Biochar trenches (or staggered biochar trenches) 2 to 3 feet deep (or deeper) and 1.5 to 2 feet wide are created in fields using simple tools. It is more convenient to make such trenches after ploughing the field. Trenches perpendicular to slopes are beneficial in the steep areas as a means of harvesting runoff water and controlling soil erosion too. Crop residue otherwise burnt openly can be collected and dumped into these trenches lengthwise. Additional biomass can be added by pushing biomass with a stick. Once the trench is filled with biomass and compacted, the trench should be covered by biomass like grass, weeds, broad leaves, etc. After covering, soil should be spread on the trench. A long mound is created as the filling is made into a heap above ground level. Some water could be used for soil compaction and to seal the mound. A small hole should be left open to light the biomass at one end, and at the other end a very small opening should be left open. Once the mound is lit, white smoke will be emitted at the other end. On the sides small holes are to be made in a lengthy biochar trench at every 10 to 15 feet. Otherwise, one could create many staggered trenches of 10 to 15 feet in length instead of lengthy single trenches. After 24 hours the biomass is converted into biochar, and the mound height is reduced due to pyrolysis. Any remaining smoke or embers should be quenched with water or covered with soil when removing the biochar from the trench.

In forested and hilly areas, staggered trenches or continuous contour trenches prepared for soil management, and water harvesting could be used to manage litter on forest floors by converting biomass into the biochar, preventing forest fires.

Major benefits of this method are:

- Convenience for farmers who would otherwise burn biomass openly, causing pollution.
- In open burning methods, biomass is mostly converted into ash and very little charcoal is formed.
- Soil also gets burnt in the process, and the burnt soil has similar properties to pottery shards.
- All the biochar and burnt soil produced in the field can be conveniently spread across the entire field. Farmers can sow seeds or saplings directly in the trenches if needed.
- Farmers need not transport the biomass to any other place for conversion into biochar.
- Farmers need not invest in technologies or obtain licenses to convert biomass into biochar.

Mound kiln

The typical rural charcoal burning mound is about 4 m in diameter at the base and about 1 m to 1.5 m high, looking somewhat like a flattened hemisphere. Six to ten air inlets are made at the base, with an opening at the top of about 20cm in diameter to allow smoke to exit during the burning. All openings must be sealed with earth when burning is complete and the mound should be allowed to cool.

Picture 33 Demonstration of mound kiln (mini)

Picture 34 A mound kiln charcoal producer

On the ground a space about 6 m in diameter is cleared, levelled, and compacted. It should be well drained. A post about 2 m tall is sometimes erected at the proposed centre of the pile of fuelwood to assist in stacking the wood, to stabilize the pile, and to provide a support for the operator when the pile is covered with earth and the top smoke hole created. The pole is usually removed before lighting to provide a central opening through the pile. A grid of crossed small logs about 10cm in diameter is first laid on the ground radially to form a circle about 4 m in diameter. The wood to be carbonized is then packed densely on this platform, allowing the fire and hot gas to circulate properly.

Picture 35 Charcoal being produced by traditional earth mound kiln method

Longer pieces of fuelwood (up to 2 m long) are stacked vertically leaning against the central pole. The shorter logs are placed vertically towards the periphery to develop a somewhat regular profile. Gaps between logs are packed with small pieces of wood to make the pile as dense as possible. The surface of the pile is packed with small fuelwood as necessary to give it as even a profile as possible and provide good support to the covering layer of earth. It is a good practice to allow the piled wood to dry out for as long as possible and to cover the pile during dry weather. To seal the pile, straw, leaves, coarse grass, etc., are spread over it and then earth or sand is spread over this layer. A sandy soil or loam with low shrinkage on drying is preferable. Plastic clays with a marked tendency to crack and shrink on drying and heating should be avoided. Charcoal fines can be mixed with earth. The thickness of the covering will vary depending on the smoothness of the wood pile, but around 10 cm to 20 cm is typical. The coating should be checked to seal all cracks and check that air holes at the base of the mound remain open.

The whole cycle takes 24 days: 4 days for charging, 6 days for carbonization, 10 days for cooling, and 4 days for discharge. Due to the high carbonization temperature (approximately 550°C) and the slow process, the charcoal produced in earth kilns has a high proportion of fixed carbon, low volatile matter, and, consequently, a low bulk density.

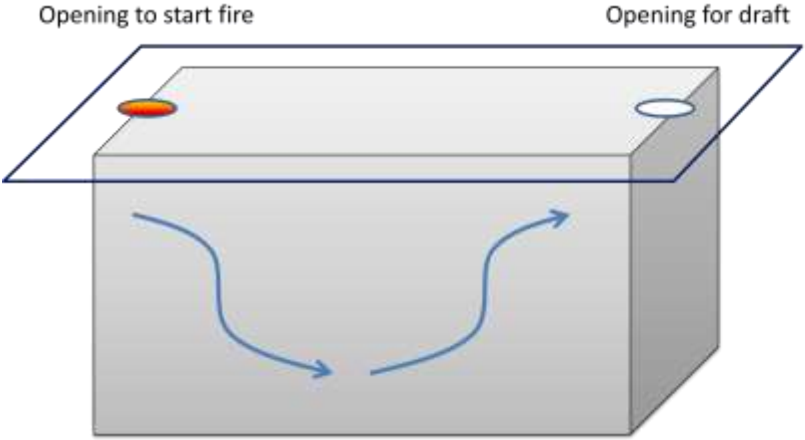
Picture 36 Holes for primary air at the base of mound

The mound is lit in the central hole by throwing in live coal. When the fire has been burning for 15 to 20 minutes, the central hole should be closed. Ventilation holes should be created around the base of the mound. As carbonization occurs, the mound sinks progressively and holes may appear; these holes should be blocked immediately using grass and sand. This is a slow process and continuous monitoring is required.

Pit kiln

The GEO biochar pit kiln is one of the simplest methods of converting crop residue and other biomass into biochar. Farmers can easily create pits or trenches and convert the biomass residue. For details see the pictures.

Picture 37 Biochar being produced by pit kiln method

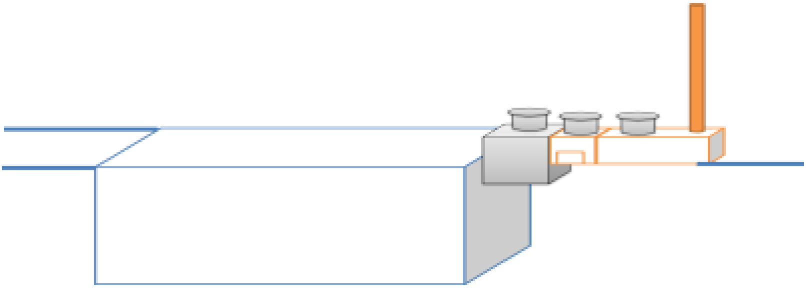


Picture 38 Design of pit kiln method

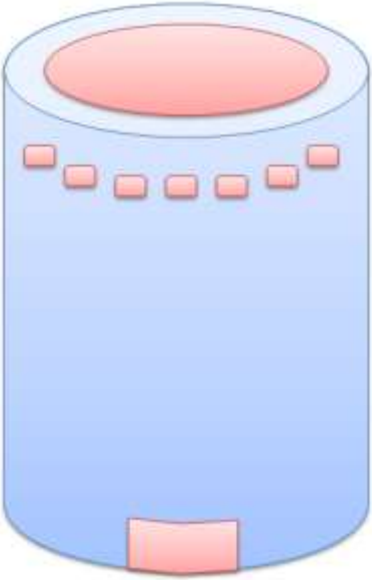
Biochar stove


Picture 39 GEO biochar stove in use

About 30% biochar production is possible with GEO biochar stove technology. Three to four days are required to produce a batch of charcoal. These stoves are highly suitable for institutional cooking as well making biochar. Additional heat is generated by flaring the pyrolysis gases and emissions are mitigated. GEO biochar stoves cost approximately Rs. 3,000 (INR) for the dimensions 2′ width x 5′ length x 6′ depth (in feet). This cost includes a tin sheet cover, the digging of the pit, a three-pot stove made with bricks and clay, and a chimney made out of iron sheet.


Picture 40 Design of GEO biochar stove

HM biochar kiln

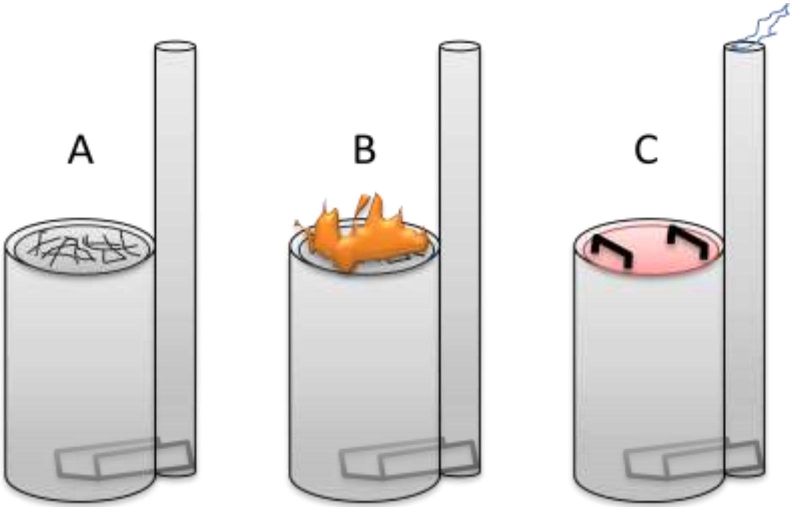


Picture 41 Design of HM biochar kiln

Bricks and clay are used in the construction of this kiln. The biomass is to be added continuously as the fire continues. The person adding the biomass to the kiln should be cautious and use a long stick to keep away from the fire. The primary air source at the bottom should be open as long as biomass is being added. As the biomass pyrolysis occurs, the biomass occupies less space and more biomass can be added. It is best to operate this kiln on calm days with little wind. As the biomass reaches a level just below the secondary air hole, the process of adding the biomass should be halted and the primary air inlet should be closed. After waiting for at least 12 hours, water should be sprinkled to extinguish the embers. The biochar can be collected immediately or after some time. This is the simplest of the processes using the waste and especially loose biomass. With this process, pine needles are often used. Pine needle management is a significant task as they often lead to forest fires, destroying many trees.

Magh biochar retort 1

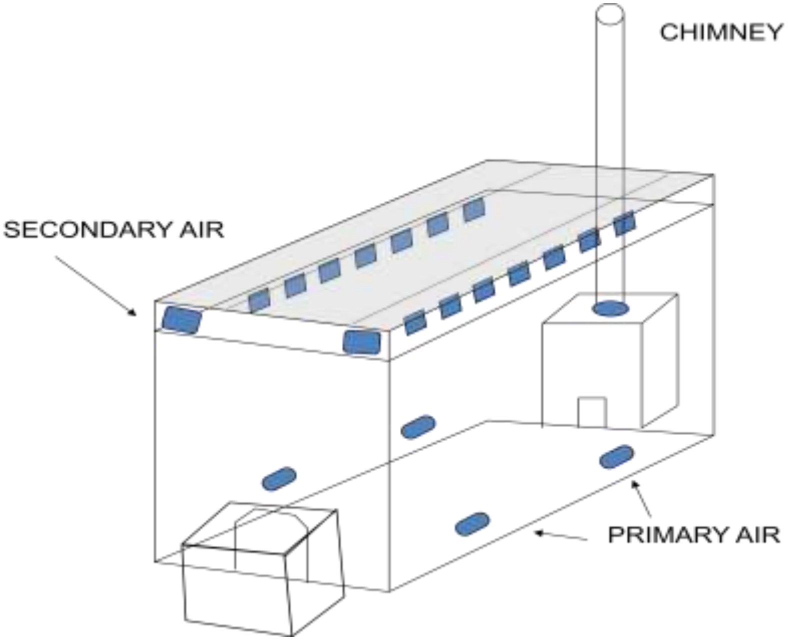
The Magh Biochar retort is a simple, low-cost biochar-making retort. In this design, a 200 litre steel drum is used. The top and bottom portions of the drum are cut open, and one of the lids is used to cover the open side on top. The biomass is dumped into the drum and lit at the top, and more biomass is added while it is still lit to fill it to the brim. In this condition, the flame is continuous. After some time, the intensity of the flames lessens. At this point, the lid is placed over the flames and is sealed with soil to prevent smoke from escaping. The smoke travels to the pipe, which is attached through a connecting pit at the bottom of the drum. The retort is then left for 24 hours while the biochar continues to form and the retort cools down.



Picture 42 Design of Magh biochar retort 1

Magh biochar retort 2

The Magh Biochar retort 2 is one of the simplest designs. This design includes an opening at the top, an opening to ignite the retort, primary air openings on the sides, and secondary air facility at the top (used only for initial combustion). These openings make it easy to control and produce biochar within three days. Training on how to operate the retort is required to ensure efficiency in biochar production. The material used for construction, the thickness of walls, and the gauge of the steel sheet is very important for durability.



Picture 43 Design of Magh biochar retort 2

Biochar retort 3

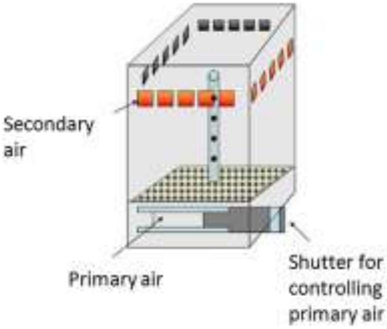
The Biochar retort 3 is a simple design using a drum to convert loose biomass into biochar. A 200 litre iron drum is used. This retort design has advantages in converting loose and light biomass material into biochar, and many similar versions of this retort are also available. In this method biomass is cooked to char rather burned for biochar production.

Picture 44 Design of biochar retort 3

All biochar is charcoal, but not all charcoal is biochar.

GEO mini metal retort

The GEO mini metal retort is also a natural draft wood-gas stove. It is a very low cost stove for heating and generating biochar. It can also be described as a mini-charcoal making metal retort. Instead of incinerating biomass generated from home gardens, any dry combustible material generated as household waste usually thrown into the garbage bin can be used. Leaf litter, dry twigs, sticks, chips of wood, wood shavings, and pellets, are suitable.



Picture 45 Design of mini metal retort

The steps involved are as follows:

- Put the biomass into the combustion chamber. Light the biomass from top. Use the heat for heating water, cooking, etc.
- Block the primary air source by closing the shutter at the bottom.
- Cover the stove with a lid and let it cool for some time.
- Turn the stove sideways to unload the charcoal produced. Sprinkle water on the charcoal embers to retrieve the charcoal more quickly.

Biochar production efficiencies

On biochar production efficiency and processes

The maximum biochar yield from retorts and kilns is by weight 33% of the biomass used - this percentage is apart from recovery of heat from some of the retorts or kilns. The success of the carbonization process is related to the raw material used, efficiency of the kiln and the skills of the operator. The mass of charcoal obtained is expressed as a percentage of the mass of wood initially put into the kiln:

$E_k = M_C/M_W$

Where E_k = kiln efficiency

M_C = mass of charcoal produced

M_W = mass of wood put into the kiln

(Stassen, 2002)

Strictly speaking, this equation refers to the *recovery efficiency*, whereas the *conversion efficiency* includes charcoal fines (rejects) that may not be packaged for sale due to their small size. Both efficiencies are calculated on wet/dry air or oven dry basis. For example, if a piece of wood weighing 100 kg has 20 kg of free water, then the actual weight of the wood is 80 kg. The moisture content is thus:

Moisture content (MC)

= Mass of water x 100% Mass of wood (dry or wet)

Wet or dry air basis: MC = 20/100 x 100% = 20%

Oven dry basis: MC = 20/80 x 100% = 25%

The equilibrium data at 1 MPa can be represented by the approximate stoichiometric equation

$$C_6H_{10}O_5 - 3.74C + 2.65H_2O + 1.17CO_2 + 1.08CH_4$$

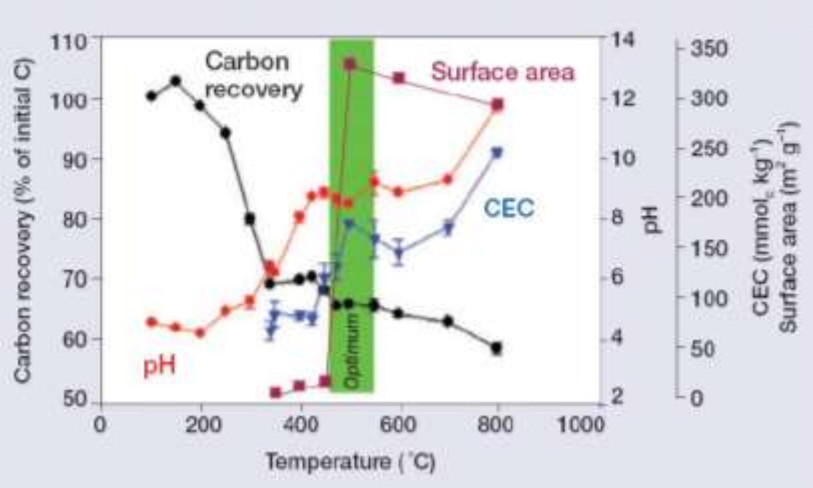
In this equation, the yield of carbon from cellulose is 27.7 wt % (i.e., 62.4 mol % of cellulose carbon is converted into biocarbon) and is not significantly affected by pressure.

The effect of temperature on thermochemical equilibrium product yields 1.0 MPa. Temperatures below 400°C are primarily of theoretical interest, as the rates of biomass carbonization are very slow in this regime. At higher temperatures, the yields of carbon, water, and methane decrease with increasing temperature, whereas those of carbon monoxide increase.

In 1909, Klason et al., represented their experimental measurements of the products of cellulose pyrolysis at 400°C by the approximate stoichiometric equation.

$$C_6H_{10}O_5 \text{ --- } 3.75CH_{0.60}O_{0.13} + 2.88H_2O + 0.5CO_2 + 0.25CO + C_{1.5}H_{1.25}O_{0.38}$$

Where the first product is charcoal and the last is tar. Using thermodynamic data available at that time, Klason estimated the heat release associated with the above equation for cotton cellulose to be 3.6% of its combustion heat.



Picture 46 An explanation for the low efficiency of conventional charcoal kilns and retorts

Pyrolysis abruptly transforms wood into a tarry vapor containing a complex soup of organic compounds mixed with noncondensable gases (including CO_2, CO, H_2, CH_4, and heavier hydrocarbons) between 250°C and 400°C. The tarry vapors quickly escape the heated region of the reactor without establishing equilibrium and without forming charcoal. Klason et al., represented these observations in the following approximate stoichiometric reaction for the carbonization of wood at 400°C.

$2C_{42}H_{60}O_{28}$ ---- $3C_{16}H_{10}O_2 + 28H_2O + 5CO_2 + 3CO + C_{28}H_{34}O_9$

Note that the yield of charcoal ($C_{16}H_{10}O_2$) in this equation is 36.7 wt %, and that the tarry vapors ($C_{28}H_{34}O_9$) constitute a significant loss of carbon.

Byproducts from pyrolysis

On byproducts from pyrolysis of biomass

Recovery of acetic acid and methanol byproducts was initially responsible for stimulating the charcoal industry. As synthetic production of these chemicals became commercialized, recovery of acetic acid and methanol became uneconomical. Charcoal manufacture is also used in forest management for disposal of refuse and weeds.

There are five types of products and byproducts from charcoal production operations: charcoal, noncondensable gases [carbon monoxide (CO), carbon dioxide (CO_2), methane, and ethane], pyroacids (primarily acetic acid and methanol), tars and heavy oils, and water. With the exception of charcoal, all of these materials are emitted via the kiln exhaust. Product constituents and the distribution of these constituents vary, depending on raw materials and carbonization parameters. Organics and CO are naturally combusted to CO_2 and water before leaving the retort. Because the extent of this combustion varies from plant to plant, emission levels are variable.

Other soil amendments

Bokashi

On soil amendment practices combining with biochar – Bokashi, Panchgavya and Raab

The Bokashi ("fermented organic matter") is a product made from bran of rice or wheat and Effective Microorganisms (EM) by Microbial Electrosynthesis (ME) technology. Bokashi is a product replete with antioxidants, which helps plants to grow. Charcoal is an important ingredient in Bokashi preparation. To make 100 pounds of bokashi the process is as follows: 30 pounds of rich soil; 20 pounds of a nitrogen-rich plant material (such as legume leaves); 20 pounds of sawdust or rotten wood (for ventilation); 20 pounds of manure (e.g., cow, pig, or chicken manure) or fermented coffee grounds. If chicken manure is used, closer to 40 pounds of manure are required, as this usually contains sawdust; 1 gallon of molasses, cane juice, or cane candy; 1 bag (about 25 pounds) of carbon (ash, charcoal dust or small pieces of charcoal, from corn husks, etc.); 1 pound of leavening agent (yeast); This mixture is turned twice a day for 15 days, at which time it is ready to use in the soil.[7]

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[7] Yovany Munguia, country director for Sustainable Harvest International http://www.mofga.org/Publications/MaineOrganicFarmerGardener/Winter20052006/Bocashi/tabid/1133/Default.aspx

Panchgavya

Picture 47 Panchagavya being prepared in a drum

Panchgavya is a concoction prepared by mixing five products of cow—dung, urine, and milk (direct constituents of panchagavya) and curd and ghee (derived products). These products are mixed in the proper ratio and allowed to ferment. The mixture, which is made using yeast as a fermenter, bananas, *jaggery*, groundnut cake, and the water of tender coconut, is a potent organic pesticide and growth promoter. The Sanskrit word Panchagavya means "mixture of five products," and it has been used in traditional Indian rituals throughout history. It is also called cowpathy treatment, as it is based on products obtained from cows used in Ayurvedic medicine and religious significance for Hindus. The *desi* (indigenous) cows are preferred, because the microbes are local. If soaked with biochar and applied to the soil, panchagavya results in greater crop yields.

To prepare the panchagavya, thoroughly mix the cow dung and cow ghee in the morning and evening, and keep it for three days. After three days, mix the cow urine and water and keep it for fifteen days, mixing it regularly both in the morning and evening. After 15 days, mix in the remaining ingredients. The panchgavya will be ready after 30 days.

Panchgavya is stored in a wide-mouthed earthen pots or concrete tanks in the open. Sufficient shade should be provided, and the contents should be stirred twice a day both in the morning and the evening. It can be diluted before use on plants and animals.

Panchgavya is commonly used as:

- As fertilizer: It is an organic growth stimulant for all types of plants.
- Seed treatment: Seeds can be treated with Panchgavya; this treatment was found useful in rhizome of turmeric, ginger, and sugarcane, with crops yielding more.
- Medicine: Panchgavya, particularly cow urine, is used in *Ayurveda*. Proponents claim that cow urine therapy is capable of curing several diseases.
- An antibiotic growth promoter, often used in fish ponds to increase the growth of plankton for fish feed.
- When fed to animals like cows and sheep, various ailments were cured. Cows yielded more milk and the egg laying capacity of poultry chicken improved. Crossbred pigs fed with Panchakavya attained more weight.

Table 5 Physical, chemical and biological properties of Panchgavya[8]

#	Parameters	
1	pH	5.45
2	EC dSm^2	10.22
3	Total N (ppm)	229
4	Total P (ppm)	209
5	Total K (ppm)	232
6	Sodium (ppm)	90
7	Calcium (ppm)	25
8	IAA (ppm)	8.5
9	GA (ppm)	3.5
10	*Fungi*	38800/ml
11	*Bacteria*	1880000/ml
12	*Lactobacillus*	2260000/ml
13	*Total anaerobes*	10000/ml
14	*Acid formers*	360/ml
15	*Methanogen*	250/ml

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[8] Source: TNAU Agritech Portal http://agritech.tnau.ac.in/org_farm/orgfarm_panchakavya.html

Raab

Raab was a system of improving soil fertility practiced in parts of Maharashtra, India. Mr. Bernard Declerq of Auroville, Pondicherry in India observed this system in use about 30 years ago. Raab is a system of charring biomass, used by some tribal communities in India. It consists of making beds of various layers of dry, half-dry and fresh woody and leafy biomass, dung and clay. The thus layered bed is fully sealed with clay and cold fired (burning in reduced conditions). In the resulting residues rice nurseries are started. The tribals affirm that this gives perfect growth of the rice plants. Charcoal bits, ash, even wood vinegar as well as sulfur that may have been absorbed by the clay would explain the growth enhancing factors of the *Raab* system.

Let the good microbes thrive and do their job —
just support them.

Traditional Practices

Telangana

☐ Traditional practices of using biochar in parts of India

In Telugu, '*Pati Matti*' refers to the old soil collected from places where there was once habitation. This soil is derived from the crumbling walls or ruins of houses. The soil contains biochar and other components derived from the waste products left by human activities. It consists of the following visible material: biochar pieces as a byproduct from the stoves and fire; soil; sand; glass pieces of bangles or bottles; pottery shards; bones of animals; pieces of brick; and iron slag. The fertility of Pati Matti is good, and it is in great demand from farmers because of the presence of these materials.

Picture 48 Pati Matti or old soil with combination of materials

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Orissa

The Munda tribal people living in parts of Orissa, who are also found across much of Jharkhand, West Bengal, Chhattisgarh and Bihar states in India use biochar to increase crop production. They mix charcoal with FYM consisting of pellets of small ruminants and cattle dung, and add the mix with the red lateritic soils that are otherwise less fertile. They cultivate vegetables and green lettuce in the well fenced plots of about one acre in size. The biochar is mostly a byproduct of the biomass cook stoves in use, which are often three-stone stoves or clay stoves. The Mundas have access to wood from the jungles, which is used as fuel for the stoves.

Picture 49 A farmer of munda tribe applied biochar in his field

Maharashtra

There is a traditional practice of using biochar in parts of Satara and Panchgani in the western part of Maharashtra, India. Biochar and ash are the byproducts of traditional stoves and water boilers. This part of Maharashtra is a high rainfall area with red soils. The use of biochar along with ash is of great value to the farmers. Each farmer uses a domestic source of biochar and ash to improve the fertility of the soils along with FYM. Strawberries and many other traditional and commercial crops greatly benefit from this practice. In floriculture, biochar is one of the mixing media in soil, as observed near Satara.

Picture 50 Biochar and ash is applied as a soil amendment

Uttarakhand

During my visit to parts of Almora and Berinag in Uttarakhand, I observed that the fields had turned dark due to the biochar added. The biochar was produced from the burning of crop residue along with pine needles and other biomass. Wheat grass and pine needles were being burnt in the fields. Biochar from cook stoves along with FYM was being added to the fields.

Picture 51 The pine needles and wheat grass remains collected and burnt in the field

Biochar direct

Application of biochar directly to the soil

Biochar alone has little value in improving the fertility of soil. However, to achieve results over a period of time, biochar can be directly applied to the soil or applied as mulch. Nothing grows on the charcoal alone. The positive effects are based on the amendments made to the soil along with the biochar - i.e., soil microbes, FYM, vermicompost, green mulch, micro-nutrients, sand, gypsum, fertilizers, silt, etc.

Biochar is directly applied to the soil based on the requirement.

Picture 52 Biochar is applied directly with out composting

Point – Biochar is applied at the point where perennial and big trees saplings would be planted, (e.g. Horticultural crops); where the density of plants per unit area would be low.

Line – Biochar is applied in the rows where plants are cultivated in rows (e.g. vegetables); where the density of plants per unit area is medium.

Area - Biochar is spread over the entire area where plants are cultivated in large numbers for e.g. paddy. Where the density of plants per unit area is high.

Table 6 Characteristics of Biochar from different Biomass

#	Characters	Paddy straw	Maize stover	Coconut shell	G.Nut shell	Coir waste	P. wood
1	pH (1: 5 solid water suspension)	9.68	9.42	9.18	9.3	9.4	7.57
2	EC (dSm^{-1}) (1: 5 soil water extract)	2.41	4.18	0.73	0.39	3.25	1.3
3	Cation Exchange Capacity (cmol(+) kg^{-1})	8.2	6.5	12.5	5.4	3.2	16
4	Exchangeable Acidity (mmol kg^{-1})	22	27	32	14	9.5	49
5	Total organic carbon (g kg^{-1})	540	830	910	770	760	940
6	Total Nitrogen (g kg^{-1})	10.5	9.2	9.4	11	8.5	1.12
7	C:N Ratio	51.4	90.2	96.8	70	89.4	83.9
8	Total Phosphorus (g kg^{-1})	1.2	2.9	3.2	0.6	1.5	1.06
9	Total Potassium (g kg^{-1})	2.4	6.7	10.4	6.2	5.3	29
10	Sodium (g kg^{-1})	14	21.5	16.8	5.2	9.6	38
11	Calcium (g kg^{-1})	4.5	5.6	8.5	3.2	1.8	11
12	Magnesium (g kg^{-1})	6.2	4.3	5.8	2.1	1.4	0.36

Note: Values are mean of triplicate sample

Biochar mulching

Biochar mulch is the application of biochar directly to the plant, similar to leaf litter mulching, stone mulching, etc. Biochar mulching has the following benefits for plants:

Picture 53 Biochar is directly applied as a mulch for plants

- Retention of the soil moisture and reduction of evaporation of moisture from the soil.
- Reduction in leaching of the biological and chemical fertilizers applied.
- Increase in the soil microbes and earthworms
- Regulation of the soil temperature, observations show that biochar compost reduces the development of soil cracks in all types of soils. Because it’s physical characteristics provide better insulation to soils and are highly effective in managing temperature.
- Suppresses weeds if thick biochar mulch is used; by blocking the sunlight sprouting of weeds and their growth are suppressed.
- Repulsion of the termites and ants that might attack seeds and plants.
- Over a period of time due to various activities the biochar mixes with the soil, which will have positive effects.
- Can increase the pH of the soil from acidic to neutral.

Biochar blends

On blending biochar with other materials for value addition; biochar compost; Geochar products

Biochar blends are biochar plus amendments made to soils. Biochar alone has little value in improving the fertility of the soil. There are multiple ways to create biochar plus products for different types of soils, crops, geographies, climatic conditions, etc., with the permutations and combinations of the list of materials in the table (in this section).

Blending the biochar with compost, mycorrhyzae, digestate, and other cultures provides a source of organic food for the microbial communities that may already exist in the soil (or that are introduced from other healthy soils).

Biochar blends are referred to by different names, including biochar, terra preta, and biochar compost. There are more than 50 commercial names, e.g., 'Geochar,' which is a biochar blend developed by the author.

Geographically, biochar application should also be based on existing conditions in the field; the right quantity of biochar application leads to better results. Optimizing biochar application based on field conditions and different types of soil is important. In this regard, biochar field trials are important. Regarding the biochar compost, biochar mulching, and biochar direct application, there is a need to create various processes and methods to suggest to the farmers in different regions based on the types of soils in use.

Biochar need not be an industrial product, although many firms have emerged recently to sell biochar as a commercial product under different names. In the past, biochar was not a commercial product. It always had ‘more than one value’ through reuse before reaching the fields to improve the soil environment and ultimately carbon sequestration. Based on the local situation biochar blends can be adopted for diverse crops, local soil microbial biodiversity, water requirements and conservation, etc.

<table>
<tr>
<td colspan="12">Humic acid
Dung slurry
Urine
Molasses
Fish oil
Seaweed
Brown sugar
Corn syrup
Compost tea
Vermicompost Tea</td>
<td colspan="12">Vermicompost
FYM
Small ruminants
Manure
Humanure
Poultry litter
Other animal dung
Worm castings
Spent mushroom
Compost
Peat
Coffee grounds</td>
<td colspan="12">Sphagnum moss
Mountain peat
Forest humus
Corn meal
Oil seed cake
Cotton seed meal</td>
<td colspan="12">Seaweed
Grass clippings
Straw
Rice husk
Coir
Coir pith
Sawdust
Alfalfa meal
Wood chips
Green mulch
Leaf litter
Cut flowers litter
Vegetable waste
Crop residue</td>
<td colspan="12">Water
Clean water
Mineral water
Magnetic water

Air
Methane
Carbon Dioxide
Nitrogen Oxide</td>
</tr>
<tr>
<td colspan="20">Soil microbes
Bacteria
Fungi
Protozoa
Nematodes
Earthworms
Arthropods
Rhizobium,
Azotobacter
Trichoderma viride
Bacillus thuringiensis
Azospirillum
Bacillus megaterium
Pseudomonas fluorescens
Glomus fasciculatum
Glomus mosseae

Effective Microorganisms
Earthworm castings</td>
<td colspan="20">Biochar</td>
<td colspan="20">Silt
Sludge
Biosolids
Clay
Pottery shards
Terra Preta nuggets
Baked earth</td>
</tr>
<tr>
<td colspan="15">Bone Meal
Fish bones
Blood meal
Fish meal
Fish emulsion
Ash
Seashells</td>
<td colspan="15">Rock dust
Glacial rock dust
Zeolite
Gypsum
Sand (quartz)
Rock phosphate
Vermiculite
Lime
Sea salt
Sea Minerals
Perlite
Azomite
Fullers earth
Greensand</td>
<td colspan="15">Synthetics
Polymers</td>
<td colspan="15">Macronutrients
Nitrogen (N)
Phosphorus (P)
Potassium (K)
Calcium (Ca)
Magnesium (Mg)
Sulphur (S)

Micronutrients
Boron (B)
Chlorine (Cl)
Copper (Cu)
Iron (Fe)
Manganese (Mn)
Molybdenum (Mo)
Zinc (Zn) and
Nickel (Ni)</td>
</tr>
</table>

Table 7 Material for biochar blends preparation

Biochar compost

Picture 54 Biochar compost

A procedure was developed to combine FYM as a source of nitrogen and other nutrients with biochar, providing a habitat for microbes and other benefits. Other components were added to improve the effectiveness of the compost, such as soil rich in microbial communities. The combination of biochar and organic or inorganic fertilizers was reported to give significant increases (up to 250%) in yield (Lehmann et al., 2002; Van Zwieten et al., 2010).

Globally, the commonly accepted biochar application rate is 1 to 5 tonnes per hectare of direct biochar application. This translates to a biochar compost application rate of about 2 to 10 tonnes per hectare. However, incremental application of biochar compost is preferred over a number of years. On the higher side, up to 30 tonnes of biochar compost can also be applied to one hectare of land. Sometimes plants can be sown in the biochar compost without mixing with soil.

The method of preparation of biochar compost is explained below.

- The method of preparation of biochar compost is aerobic.

- Biochar and FYM being main ingredients, other additions in the biochar compost could be based on availability of pottery shards, fish meal, brick pieces, burnt earth, etc.
- *Jaggery*, molasses, or sugars should be added while mixing the biochar compost.
- There should be enough moisture during preparation, and it should be prepared under normal temperatures in a shady place.
- Minimum number of days required for preparation of biochar compost is 15 days.
- The field should be wet or biochar compost should be applied after the rains; this helps in the easy spread of soil microbes.
- Silt collected from dried surface water bodies, its application is also important along with the biochar compost for the fields.

Picture 55 Biochar compost preparation is in process on a small scale

Biochar compost characterization

Picture 56 A woman farmer adding materials for biochar compost preparation

As per the results of the proximate analysis of biochar and biochar compost, of the two biochar sources, rice husk biochar showed a very high percentage of ash (68.7%) and a very low percentage of fixed carbon (8.99%). On the other hand, *Prosopis Juliflora* biochar showed significantly higher fixed carbon (85.36%) and low ash (2.7%) content. The moisture content was similar in both biochars, but due to the high carbon content, the energy value of the *Prosopis Juliflora* biochar was 5 times higher than that of rice husk biochar. Rice husk biochar showed a moderate amount of volatile matter (VM) (18.42%), while *Prosopis Juliflora* biochar showed low VM content (8.31%). In comparison, Deenik et al. (2011) reported 35.1% to 96.1% fixed carbon, 1.17% to 18.1% ash content and 2.9% to 63.4% VM content in various biochars. Deenik et al. (2011) classified biochar with 23.9% VM was classified as moderate VM biochar and biochar with 7.68% VM was classified as low VM biochar. This suggests that both biochar sources were low to moderate VM biochars, and as such did not pose a significant risk of N immobilization when used as soil amendment.

Biochar compost showed lower VM, fixed carbon and calorific value, and higher ash and total moisture content due to mixing with

FYM and other processing described in the methods section. Independent analysis at the College of Agriculture, Raichur, Karnataka, India, showed that biochar compost (Geochar 1)[9] was an excellent source of carbon and various agronomic nutrients.

Cation exchange capacity (CEC) measurement indicates that preparing biochar compost increases the CEC from 2.56 to 3.4 milliequivalents per gram. Analysis of *Prosopis Juliflora* biochar and biochar compost using standard soil testing methods shows that biochar compost contains 149% higher salt content, 6% higher Fe, 11% lower Zn, 22% lower Mn, 24% lower K_2O, and 35% lower Cu concentration. The pH of biochar compost was slightly higher than the *Prosopis Juliflora* biochar.

This shows that the process of preparing biochar compost improved the nutrient holding capacity as indicated by the higher CEC and concentration of some nutrients, while diluting other nutrients. Higher CEC in biochar composts indicates that the addition of biochar compost is more useful in improving the nutrient use efficiency of applied fertilizers and crop yields than the addition of biochar alone. Crop yields increase from 200% to 400% when biochar plus (amendments) are introduced to the soil. Some of the methods developed by author are described below.

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[9] The biochar compost was prepared at GEO RC and given to the Raichur Agriculture University, Karnataka, India.

Geochar - 1

Biochar (48%), FYM[10] (48%) and natural soil (about 3%) by volume were mixed to prepare this biochar compost. The source of biochar can be any biomass, such as *Prosopis Juliflora*, rice husk, crop residue, etc. The natural soil was collected and added from an undisturbed forest place or a protected area with good biodiversity. The mixture was moistened with *jaggery* water i.e., 1 kg of *jaggery* is added to 100 litres of water. For every 1000 kgs of biochar compost preparation at least 1 kg of *jaggery* is required. Fermented material such as molasses or sugarcane juice can also be used if *jaggery* is unavailable. Many other additives can also be used, such as toddy collected from

Picture 57 Biochar Compost Preparation, adding Jaggery water

Picture 58 Basic ingradients for biochar compost preparation

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[10] Vermicompost or small ruminant manure can also be used.

palm trees or any beverage with high sugar content, if nothing else is available. Soil microbes love the above materials and thrive.

During the initial stages of preparation, the temperature of the biochar compost could reach 65°C to 70°C. The temperature should be kept below 50°C by sprinkling water and keeping it cool. The material can be covered with moistened straw and gunny bags. The material should be mixed every day for 15 days while adding jaggery water. After 15 days (the minimum time required), the mixture cools off to around 25°C to 30°C, at which time the geochar-1 is ready for application[11].

Picture 59 Higher temperatures indicate biochar compost is not complete. Below 37 degrees centigrade indicates that biochar compost is ready for application

To test for biochar, when biochar compost is added to a glass of water, more than 95% of the Geochar-1 should settle or suspended down within two hours—there should be very little floating matter. This simple test was developed to show that the biochar compost

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[11] The material was prepared in a semi-arid place near Jangaon, Telangana state, India, around 18 degrees north latitude and 79 degrees east longitude

was ready to use—that it is well oxidized, has lost hydrophobia, and is properly incorporated with the manure.

There are two other variations of Geochar 1, namely:

Geochar 1A prepared with green manure (10%), biochar (40%), baked earth (10%), and compost (40%).

Geochar 1B prepared with Geochar 1 biochar (45%), baked earth (10%), and compost (45%). This is prepared without green manure.

Picture 60 A farmer preparing the biochar compost

In biochar compost preparation, commercially available soil microbes can be added such as Rhizobium, Azotobacter, Trichoderma viride, Bacillus thuringiensis, Azospirillum, Bacillus megaterium, Pseudomonas fluorescens, Glomus fasciculatum, and Glomus mosseae. Once prepared, this biochar compost should be kept in a shaded place. The *jaggery* water should be added to the biochar compost one day before transferring it to the fields for application. This keeps the microbial population viable during transport.

Geochar - 2

Geochar-2 is prepared by soaking biochar in human urine. It is then dried in a shaded place and applied directly to the soil. Geochar–2 can also be used as biochar in Geochar-1 instead of applying fresh biochar.

To prepare various blends of Geochar-2, the biochar can be soaked in other material such as animal urine or livestock dung slurry. To collect human urine, biochar urinals can be designed for use.

Analysis of control and urine-treated biochar shows an increase in K_2O concentration (from 109 kg/ha to 143 kg/ha) and a decrease in pH (from 8 to 7.8) and salt concentration (from 1.57 to 0.63 mole/cm), while P_2O_5 concentration was not affected.

Whether biochar reaches the soil directly or indirectly after use, it is still called biochar.

Geochar - 3

Picture 61 Author testing the alkalinity of soil by walking in a paddy field (alkaline soils are slippery)

Biochar experiments were conducted by author in alkaline soils. Crops were failing due to excessive alkalinity of the soils; therefore some farmers left the fields fallow. The soils were tested for the alkalinity and other parameters. A specific biochar blends formulation and method of application was prepared for alkaline soils.

Biochar was flushed with running water to remove any ash traces. Field treatment occurred before the application of geochar-1. Sand and gypsum were added in the field. Other nutrients or trace elements were added as per the requirements. Geochar 1 was prepared using FYM. Soil microbes like Trichoderma Viride, Azospirillum, Azotobacter, and Pseudomonas fluorescens, were procured and added to the geochar-1, as was *jaggery* water.

Steps to follow in implementation:

- Use green manure and plough it into the soil

Table 8 Green Manures

Legumes		Non-legumes	
Green manure	Green leaf manure	Green manure	Green leaf manure
(eg.)Daincha Sunhemp Kolinji	(eg.) Gliricidia Cassia Pongamia glabra	(eg.) Sunflower Buck wheat	(eg.) Calotropis Adathoda *Thespesia*

- Spread sand and biochar in the field and plough, preferably during dry periods or when the soil is dry
- Spread Gypsum, farmyard manure or vermicompost, and macro and micro nutrients as per the requirement.
- Spread the treated biochar along with *Tricoderma Viridea, Aztobactor*, *Azospirillum*, *Pseudomonas Fluoresence*, and other soil microbes.
- Sow the seeds

The number of tillers in a paddy crop increased when treated with biochar as compared to the control plot. For the count of tillers in Paddy, a sample of 10 planted bunches taken at random. Seed variety is *Sona Masuri*.

Table 9 Tillers as observed in the paddy field (in numbers)

	Average	Maximum	Minimum
Alkaline field treated with biochar	43	52	27
Control Field	29	35	23

In a comparison of biochar treated and control fields, the soil condition in the treated paddy field improved considerably. While walking in the field bare footed, one could feel the firmness and evenness of the soil. In the untreated field the soil was crumby and slippery.

Table 10 Soil characteristics before biochar amendments

	Soil samples collected - Name of the farmer			
	Shivaji	Janardhan Reddy	Narasimha Reddy	Venkat Reddy
pH	8.81	8.86	9.21	9.04
E.C.	0.79	0.83	0.33	0.33
O.C.	Low	Low	Low	High
P (Kg/acre)	17	13.6	15.3	17
K (Kg/acre)	130	150	125	145
Zinc (Kg/acre)	0.65	0.65	0.65	0.65
Gypsum (Kg/acre)	324	440	405	344

Biofertilizers or pesticides (e.g., Aztobactor, Trichoderma Viride, Azospirillum, and Pseudomonas fluorescence) are available in the market. One kilogram of each is required for application to one acre of land. To enhance the number of microbes before application the following method is followed: mix one kilogram of biofertilizers or biopesticides with 50 kgs of well-cleaned biochar and 50 kgs of vermicompost or FYM. Pack the material under straw and gunny bags, and cure it by sprinkling with *jaggery* water and mixing it over 15 days.

Table 11 Biochar amendments recommended for the above fields

Biochar (per acre)	1,500 kgs*
Sand (per acre)	10 tractor loads (@ 5 tonnes per tractor load)
Gypsum (per acre)	300 kgs
Vermicompost / FYM (tonnes / acre)	4 tonnes
Urea (N) (Kgs / acre)	50 kgs
Super Phosphate (P) (Kgs / acre)	70 kgs
Muriate of Potash (K) (Kgs / acre)	10 kgs
Zinc (Zn) (Kgs / acre)	20 kgs

**The biochar application is recommended here for one year. Incremental application of biochar is needed over a period of 5 to 10 years and the total quantity of biochar applied is about 10 tonnes per acre.*

Application of biochar

On application of biochar; interval and processes

Biochar has been in use in parts of India for centuries. Biochar is added along with FYM or compost every year. As the retention time of biochar in soil is very high, the impact is cumulative. In many villages in India, agriculture is at least a few hundred years old. The existing biochar in the soil found in the majority of the fields is a cumulative contribution of the farmers – sometimes intentionally and other times by chance. Biochar is found in all types of soils. As this practice has become traditional, it is sustainable, and can be applied irrespective of climate and soil conditions. Biochar or biochar compost can be applied to the soil in different ways.

Picture 62 Comparision without and with biochar growth of plants – Tomatoes (left) and Brinjal (right)

Incremental biochar compost application

Incremental application of biochar compost is preferred, as it has the following advantages:

Picture 63 A farmer applying biochar to a plant

- Soil microbes adapt to the new environment altered by the biochar compost application over a period of time.
- In the initial phase, some biochar removes salts and other poisons from the soil, which is a process that requires some time. The later subsequent application of biochar compost improves soil conditions.
- With the application of biochar compost structure and texture of the soil changes over a period of time.
- Incremental application addresses the sustainable use of biomass, which is converted into biochar.
- For the user, the burden of the cost of application of biochar compost is not high if applied incrementally.

Application processes

Soil tests are important for understanding various other parameters; necessary amendments are made accordingly.

Picture 64 Biochar compost when applied to soil, the soil turns dark (biochar, soil, biochar+soil)

- Biochar compost application yields immediate results in the field.
- Results are slower with the application of biochar directly to the field.
- The combination of both methods—biochar and biochar compost—can be chosen. Preference should be given to biochar compost application.

All farmers can adopt biochar, and one need not be in a hurry to apply large quantities to achieve a bumper yield. Annual incremental application is more sustainable for the farmer and for the environment.

Quantity for application

☐ On quantity of biochar application

The quantity of biochar suggested for a field that is devoid of biochar, where such traditional practices were not in place, is in tonnes per hectare. However, there is a need to assess the total biochar in each field and suggest the quantity of biochar accordingly. Still, the quantity of biochar for different climatic conditions and soils should be evolved through standard experiments conducted simultaneously in different latitudes and longitudes.

Picture 65 Biochar applied in paddy field

Picture 66 Biochar applied in field and ploughed for proper mixing

Picture 67 Biochar applied in cotton field

Biochar additions

Silt

☐ Biochar applied along with other materials – silt and compost tea

Some farmers apply silt collected from surface water bodies like ponds, lakes, water tanks, streams and rivers. Soil carbon and fertility of soil increases due to silt application. Along with biochar, silt application is beneficial, especially in light soils. One of the case studies from part of Andhra Pradesh, India, indicates that the sediment deposited in the water tanks provided a significant amount of nutrients (N, P, and K), were richer in organic carbon and microbial activity, and thus could act as fertilizer substitutes for crop production. Because loss of microbial diversity through erosion from fields is one of the important factors for land degradation. Returning tank sediments rich in nutrients, organic carbon, microbial biomass carbon, and microbial population would help in improving the microbial diversity and biological activity in farm soils. Thereby improves soil quality

Picture 68 Silt collected from water bodies when they dry up, is traditionally applied to the fields

and crop production. The feasibility of desilting operations and returning such large amounts of sediment to agricultural fields was assessed by determining the sediment quality in terms of nutrients, organic carbon, biological properties, and their economic value as a source of plant nutrients. Analysis of sediment samples showed an average of 720 mg nitrogen (N), 320 mg phosphorus (P), 310 mg potassium (K), and 9.1 g of organic carbon per kg of sediment.[12]

Compost tea

Compost tea is a liquid extract or dissolved solution, but not simply a suspension of compost. It is made by steeping compost in water for three to seven days. It was discovered in Germany and became a practice to suppress foliar fungal diseases by nature of the bacterial competition, suppression, and antibiosis on the leaf surface (phyllosphere). Compost tea has also been used as a fertilizer, although lab tests show it is very weak in nutrients with less than 100 ppm of available nitrogen and potassium. Other salts present in the tea solution are sodium, chlorides, and sulphates. The extract is applied as a spray to non-edible plant parts, such as seedlings, or as a soil-drench (root dip), or surface spray to reduce the incidence of harmful phytopathogenic fungi in the phyllosphere. The biochar soaked in compost tea can be applied to the soil.

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[12] "Economic evaluation of sediments as a source of plant nutrients" www.ias.ac.in/currsci/oct252008/1042.pdf

Biodiversity

Biochar for conserving soil microbial biodiversity

Biochar protects and enhances both macro and micro biodiversity. Microbial habitats are enhanced through the unique structure and properties of biochar. Biochar-amended soils have higher microbial biodiversity.

We are currently experiencing a loss of soil biodiversity, which has an adverse impact on terrestrial and global ecosystem processes. Only by knowing and understanding life in the soil can one begin to conserve and better utilize its life-sustaining services. There are many pathways through which the production and use of biochar in agriculture at all scales can preserve and enhance native biological diversity. A study published by the US National Research Council in 1993 notes: "Our lack of knowledge of microorganisms and invertebrates, which are estimated to make up as much as 88% of all species, seriously hampers our ability to understand and manage ecosystems".

Soils are providers, holders, and generators of biodiversity, but they are also one of the most undervalued and poorly researched habitats on earth. At the very time soil ecologists are beginning to uncover the magnitude and importance of life in the soil, the resource itself is literally disappearing off the face of the earth. Human activities are the greatest threat to soil biodiversity through habitat destruction, pollution, and climate change.

Biochar amended soils show high levels of microbial biodiversity. Biochar is like a coral reef for the soil, creating a great habitat for all soil life diversity. The surface area of biochar is very high—a spoonful of biochar has the surface area equivalent to a football field. This surface area in biochar combined with other conditions like, moisture, air, absorbed nutrients, regulated temperature, etc. make a very convenient living environment for soil microbes.

The staggering diversity of soil biota may be orders of magnitude higher than the above-ground diversity of plants and animals, but as yet there is no exhaustive census of even one natural habitat. According to the Global Biodiversity Assessment, "a single gram of temperate forest soil could contain 10,000 million individual cells comprising 4,000-5,000 bacterial types, of which less than 10% have been isolated and are known to science".

Soil biodiversity influences a wide range of ecosystem processes that contribute to the sustainability of life on earth. For example, soil organisms maintain critical processes such as carbon storage, nutrient cycling, and plant species diversity. Soil biodiversity plays a role in soil fertility, soil erosion, nutrient uptake by plants, soil organic matter formation, nitrogen fixation, biodegradation of plant and animal material, hazardous waste reduction, production of organic acids that weather rocks, and control of plant and insect populations through natural biocontrol.

Biologically fixed nitrogen (primarily nitrogen-fixing microorganisms that live symbiotically on the roots of leguminous plants and trees) makes an enormous contribution to global agricultural productivity. The living microbes, fungi, and invertebrates found in soil are responsible for decomposing carbon and nitrogen and making them available for plant growth, while at the same time contributing to the rate of production and consumption of carbon dioxide, methane, and nitrogen.

Conventional soil science has generally relied on the use of purchase farm inputs to overcome constraints and modify the soil environment. Biochar and soil microbes minimize the use of purchasing inputs and maximize the efficiency of soil microbes use. Soil microbes are important and should be recognized immediately for their role in food security, poverty alleviation, and development. The importance of microbial biodiversity in variety and numbers coexisting with human living environments should likewise be recognized. Microbes serve natural ecosystems; without microbes ecological disasters would occur, affecting human existence.

To inoculate native soil microbes with biochar, local biodiversity should be maintained in pockets. Only in the presence of beneficial soil microbes can biochar produce a greater biomass yield.

Microcosm and Macrocosm

Soil microbial biodiversity is the greatest contribution by biochar. Other biodiversity is a reflection of this microcosm. Put another way, if high macrocosm (macro biodiversity – flora and fauna) exists it signifies that high soil microbial biodiversity is possible for that ecotype.

The author has developed an area with 200 species of plants conserved on half–an-acre of land to develop soil microbial culture for inoculation into biochar[13]. Chemical pesticides and fertilizers have never been applied in this environment. This natural soil has diverse indigenous soil microbes.

Soils are often ignored in research on biodiversity, despite the fact that they are a critical life-supporting surface upon which all terrestrial biodiversity depends.

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[13] GEO Research Centre, Peddamaduru village, Devaruppala Mandal, Telangana, India.

Soil

Soil is considered the "skin of the earth" with interfaces between the lithosphere, hydrosphere, atmosphere, and biosphere. Soil is the mixture of minerals, organic matter, gases, liquids and a myriad of micro- and macro-organisms that can support plant life. It is a natural body that exists as part of the pedosphere and it performs four important functions: it is a medium for plant growth; it is a means of water storage, supply and purification; it is a modifier of the atmosphere; and it is a habitat for organisms that take part in decomposition and creation of a habitat for other organisms.

On the characteristic of soil amended with biochar – physical, chemical and biological aspects

Picture 69 Soil is precious, there is a need to be conserved and managed

Biochar application reduces the burden of farmers in several ways, namely by maintaining and enhancing soil fertility. Biochar supports soil life functions at the micro and macro scales, as elaborated below.

Physical

- Biochar reduces soil bulk density.
- Biochar increases soil aeration.
- Biochar changes the soil structure and texture through changes in physical and chemical properties.
- Biochar lessens the hardening of soils.
- Biochar helps to reclaim degraded soils.
- Increased Cation Exchange Capacity: biochar has a greater ability than other soil organic matter to adsorb cations per unit carbon (Sombroek et al., 1993) due to its greater surface area, greater negative surface charge, and greater charge density (Liang et al., 2006). Therefore, biochar offers the possibility of improving yields (Lehmann, 2007).

The dark soils

Over a period of time biochar soils turn dark. It is not always easy to identify biochar soils through images or photos. There are various natural and anthropogenic factors responsible for the dark colour of the soil. Field to field distinction is possible through the colour. Human interventions, such as burning of crop residue, application of fertilizers, soil carbon, soil moisture, silt, and the status of the field (fallow/current, ploughed/unploughed, with/without crop, irrigated/dry, etc.) can alter the colour of natural soils.

Chemical

- Biochar reduces soil acidity by increasing pH (also called the liming effect).
- Biochar helps soil retain nutrients and fertilizers (Lehmann, 2006 in Hansen, 2008).
- The application of biochar improves soil fertility via two mechanisms: (1) by adding nutrients to the soil (such as K, to a limited extent P, and micronutrients); (2) by retaining nutrients from other sources including nutrients from the soil itself. The main advantage is the latter. In most situations, biochar additions only have a net positive effect on crop growth if nutrients from other sources such as inorganic or organic fertilizers are also applied.
- Biochar increases C, N, and P availability to plants, because biochar absorbs and slowly releases fertilizer.
- Biochar increases in the soil levels of available Ca, Mg, P, and K.
- Biochar helps to prevent fertilizer runoff and leaching, allowing the use of less fertilizer and diminishing agricultural pollution to the surrounding environment.
- Biochar mitigates the impact of hazardous pesticides and nitrogen fertilizers on the local environment and ecology.
- Biochar absorbs complex fertilizers and pesticides in soil, thus lessening their impacts.

Biological

A good soil should include a wide and balanced variety of life forms, including bacteria, fungi, protozoa, nematodes, arthropods, and earthworms.

Picture 70 Fungus in soil is important

- Biochar increases soil microbial respiration by creating space for soil microbes.
- It increases soil biodiversity and soil-life density in the presence of organic carbon.
- Biochar increases arbuscular mycorrhizae fungi. Soil aggregation also improves due to increased fungal hyphae. The commercially available soil microbes can be used for inoculation include Rhizobium, Azotobacter, Trichoderma viride, Bacillus thuringiensis, Azospirillum, Bacillus megaterium, Pseudomonas fluorescens, Glomus fasciculatum, and Glomus mosseae.

If application of biochar discriminates against some of the life natural to the soil, it is unclear what multiplier effects may present to cause disharmony in the soil environment. Thus, understanding how much biochar is good for a particular soil is important.

Termites

Termites are a group of eusocial insects that, until recently, were classified at the taxonomic rank of order Isoptera, but are now accepted as the infraorder Isoptera, of the cockroach order Blattodea.

Termites are often a problem in dry land areas after rains or in winter. In experiments, the author found lower occurrence of termites in the presence of biochar compared to control fields. Biochar helps to lessen the impacts of termites on the biomass in agricultural fields. Termites are sometimes responsible for destroying young saplings and roots, though they can also benefit plants by bringing minerals up from deep down in the soil.

Picture 71 Termites on earth cause extensive damage

Picture 72 Biochar and ash is used as base for rice husk to repel termites from eating.

Earthworms

"Earthworm" is the common name for the largest members of Oligochaeta in the phylum Annelida. An earthworm is a tube-shaped, segmented animal commonly found living in soil, that feeds on live and dead organic matter.

Picture 73 The density of earthworms over a period of time increase in soil, if biochar is added.

The density of earthworms in biochar fields varies based on several factors. In freshly added biochar plots, the density of earthworms is lower because of the abrasive nature of the fresh biochar. The density of earthworms depends on the type of biomass used to produce the biochar, the quantity of biochar applied, and the size of biochar particles in the soil. The presence and density of earthworms increase in soil treated with biochar over time.

Table 12 The number of earthworms observed in the experimental plots

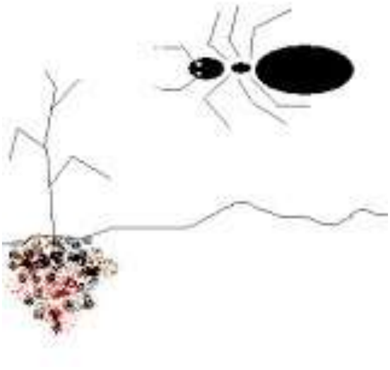
#	**Biochar in % age**	**Earthworms in numbers**
1	16	4
2	5	17
3	3	8
4	0	7

There is an increased chance that earthworms will occur in the soil just underneath the pure biochar layer. Microbial life in the presence of biochar also increases the process of vermicomposting.

Based on further observations, effective vermicompost pits can be designed with different percentages of biochar blends. Any methane produced during the vermicomposting process is absorbed by the biochar.

Ants

Ants perform many ecological roles that are beneficial to humans, including the suppression of pest populations and aeration of the soil. However, their ability to exploit resources brings ants into conflict with humans, as they can damage crops. Ants also prey on certain harmful insects. Ants dominate most ecosystems, and form 15% to 20% of the terrestrial animal biomass.



Picture 74 Ants repel in the presence of fresh biochar applied in the soil

Ants were observed transecting the experimental pots. Ants are more repellant to the freshly added biochar, and over a period of time the biochar's impact on ants lessens. This is positive, because fresh biochar can repel ants when needed. To compare soil with and without biochar, the author sowed Brinjal seeds in 12 pots. In the 3 control pots, seeds were eaten away by small red ants. The 6 pots with a mix of 30% biochar and 70% red soil were untouched by ants.

The percentage of seeds germinated increased without killing the ants. Biochar can be added along with the seeds.

The second important application is in the vermicompost pits where sometimes ants eat the earthworms. To avoid such a problem biochar can be added to vermicompost pits.

Farmers know that wherever biomass is burnt in the fields crop grows stronger, healthier and better.

Water

Biochar improves water use efficiency and permeability. It also improves soil moisture retention and conserves water, securing crops against drought. Biochar cleans polluted water to some extent through filtration, thereby providing clean water to the environment and plants. It also reduces fertilizer leaching and ameliorates dead zones in water bodies. Here are some innovative methods of using biochar for conservation and management of water given to plants.

Biochar for water quality, conservation and efficient usage

Being sensitive to Plants

Consider plants as sensitive: they need to be taken care of, because some plants are domesticated for the benefit of human beings in the name of agriculture. Poor treatment on the part of humans towards plants is known as ‘inplant’ behaviour. Throwing water on the ground and expecting the plant to consume it without waste is nearly impossible. The loss of water through percolation and evaporation is almost inevitable. As plants do not move and have limited root systems, one needs to be innovative and implement good practices to support them. Plants are often selected for the benefit of humans and not by their suitability in a given space.

Terra Preta nuggets

Terra Preta (TP) nuggets are small balls of burnt clay embedded with charcoal. They are created by mixing clay (~40%), biochar (~50%), and ash (~10%) with water. Some of this mix is rolled by hand into small balls or nuggets, which are dried in the sunlight for about three hours at 20°C to 30°C in airy conditions. These nuggets are then baked at around 700°C to 900°C for one to two hours[14]. After baking, the TP nuggets are hard; if properly formed, they should not dissolve or crumble when immersed in water. This is a hybrid product sharing characteristics with biochar and pottery shards.

Picture 75 TP nuggets

Picture 76 A flower pot with TP nuggets

When produced in large numbers, TP nuggets can be used for horticulture, where the application is for each plant rather than

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[14] For small scale production, the nuggets can by baked using TLUD stoves such as Magh-1.

spreading. The main advantage is water absorption and retention. Nuggets can be used in flower pots, especially when watering is irregular. TP nuggets can also be used in the compost-making processes for enhanced microbial activity and to increase soil microbes population. They also have the advantage of being easy to store and transport. TP nuggets can be used as filtering media for water purification, in aquarium water filters, as gravel in aquariums, etc. These nuggets are relatively heavy; unlike biochar, portions of which can wash away or move as time passes, TP nuggets remain relatively static when applied to fields.

The multiple use of biochar as "Biocharculture" makes it sustainable and adaptable by communities.

Clean water

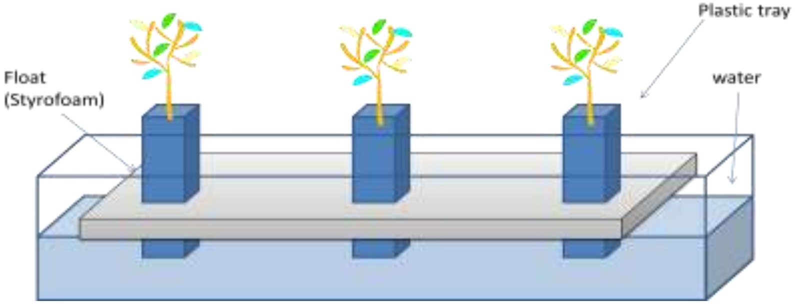
Clean water is required for plants for effective uptake of nutrients dissolved in water. As activated carbon, the use of biochar is very well known in water purification processes. When purified with biochar, the colour of water is clear, odour and harmful elements are removed.

A simple test is employed to test the seepage of water and its quality. Two pots are used— one with red soil and another with red soil and biochar. These pots have holes in the bottom and are placed on ceramic plates. An equal quantity of water is added to both the pots simultaneously. It is found that water is better retained in the pot with biochar and the seepage is slower. The pot without biochar released turbid water, while the water from the biochar pot was clear.

Charcoal increases the ability of sandy soils to retain water and nutrients (Laird, 2008). However, a greater surface area is likely to result in greater water-holding capacity” (Lehmann, 2007). Adding 20 grams of biochar per kilogram of soil increases the soil's water retention potential by 15% (Laird, 2009 in Barinkick et al.). The effect of biochar on water relationships in soil have not been thoroughly investigated, but could potentially lead to important returns (Lehman, 2007). Biochar improves ground and surface water quality by reducing leaching losses (Laird, 2008).

Floatigation

Floatigation refers to growing plants on floats, where the water (including fertilizers) is taken up through capillary action. The plant absorbs the required quantity of water aided by the capillary action of biochar and soil. Water supply can be adjusted by raising or lowering containers into the water as required on the floats.



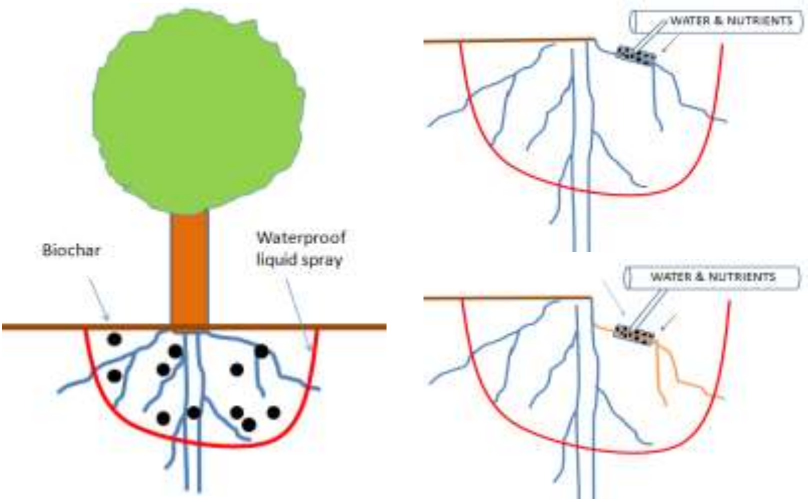
Picture 77 Floatigation setup demo sketch

Picture 78 Demonstration of floatigation

Rootigation

In this growing method, a circular pit is prepared around the plant without damaging the roots. Part of the soil in the pit should be covered with polyethylene or biodegradable wax spray or covered with waterproof material. Biochar compost is then applied in the pit.

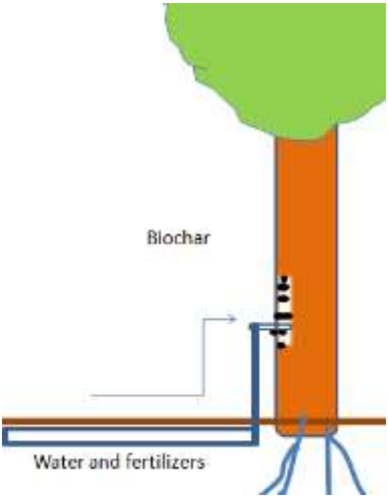
Other methods are small pouches of biochar compost are then attached to the roots of the plants. Pouches can be made of durable material. Water is fed to the plant by a drip irrigation system. Root-root Graft: Grafting a root of a plant to another root of a similar or different species for better uptake of water.



Picture 79 Showing rootigation method

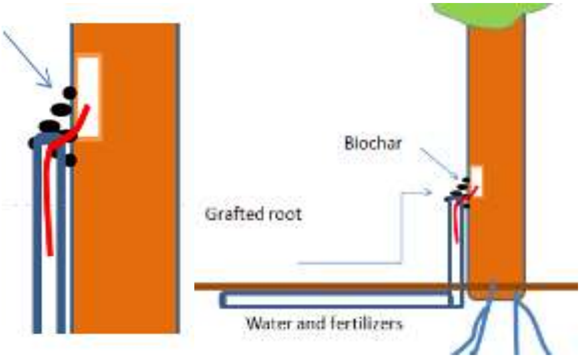
Sapigation

In sapigation, sapwood is exposed linearly, a layer of sterile biochar powder is applied to it, and it is wrapped in a muslin cloth or synthetic net. Water is fed to the plant slowly via drip irrigation. Fertilizers can be mixed in with the water in diluted form so that the plant consumes them slowly and is not exposed to high concentrations of nutrients. This system benefits from biochar's superior storage capacity and affinity for water.



Picture 80 Sapigation method

In this another method of sapigation, the sapwood of a tree is grafted onto roots of the same, similar, different species. Water-loving roots (i.e., roots that remain



Picture 81 Saptation with a grafted root

submerged in water constantly) are more beneficial for grafting. The grafted roots will take the required amount of water from the water pipe and transfer it to the plant. Biochar is used to cover the exposed root.

Parasitic plants could be encouraged to grow on certain plants and suppress the growth of parasitic plant shoots. Parasitic plants have a modified root, the haustorium, that penetrates the host plant and connects to the xylem, phloem, or both. These roots could be used for sapigation.

Picture 82 Parasitic plant growing on a mango tree

Note: Research should be conducted to further improve this method. Usually the capacity of parasitic plants to take on moisture and nutrients is very high. The rate of transfer of the same to the host plant would be high if properly facilitated.

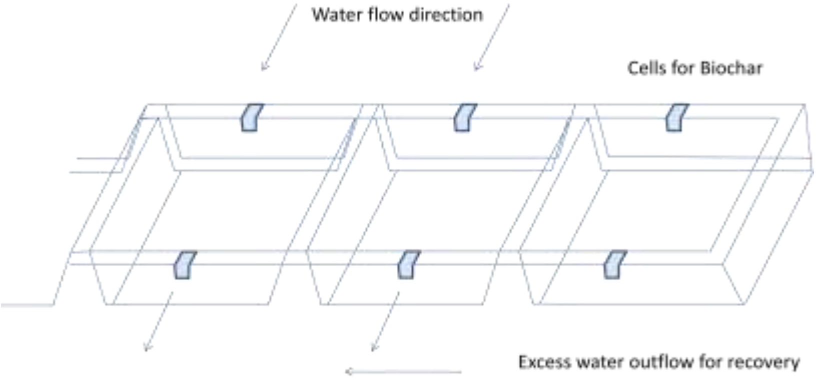
Biochar need not be applied where soils are very good.

Perchigation

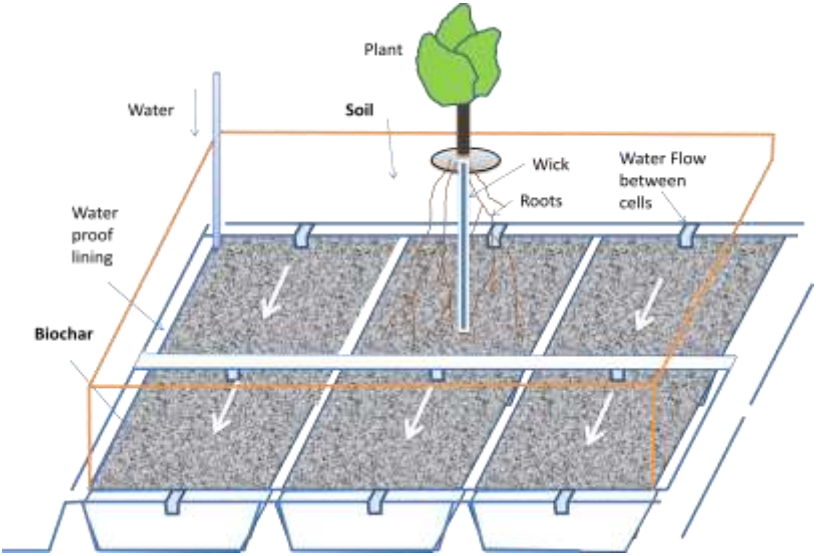
Perchigation is a means of creating a shallow, perched biochar aquifer for irrigation. This method is highly suitable for semi-arid and arid areas to reduce water evaporation and store water under the soil. Perchigation prevents water from going deeper into aquifers, thereby increases the water availability to reach plants.

Biochar absorbs the water and soil nutrients. By absorbing harmful pesticides and chemicals mitigates their impact on soil. Perchigation also has the advantage of reducing emissions from the soil. Biochar has the capacity to purify water in areas where polluted water is used for irrigation.

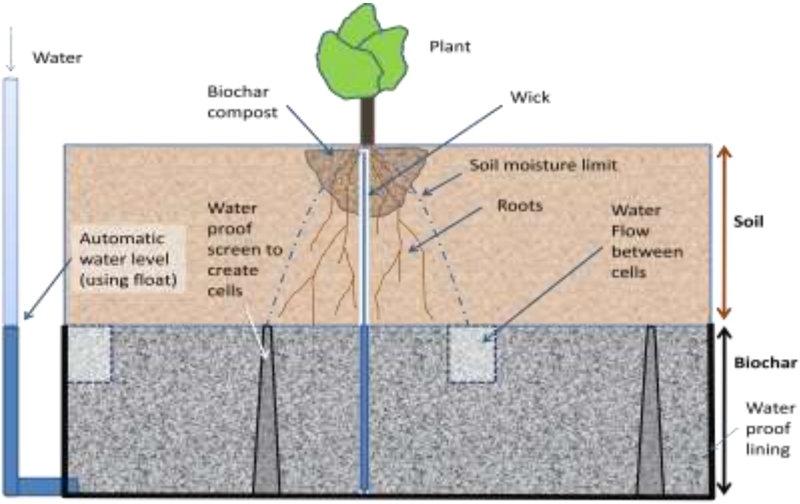
The perchigation method is highly suitable for the cultivation of vegetables, tubers, cereals, chilies, cotton, etc., and for adoption in the fields, greenhouses, polyhouses, etc.



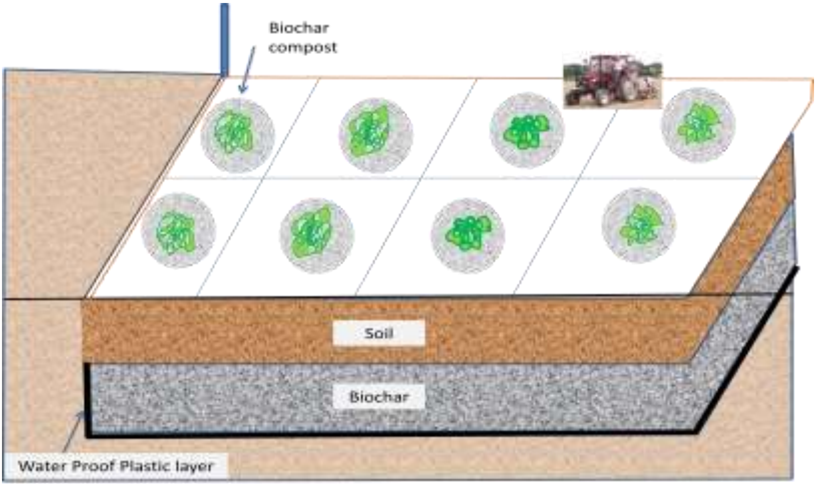
Picture 83 Details of perchigation 1



Picture 84 Details of perchigation 2



Picture 85 Details of perchigation – cross section

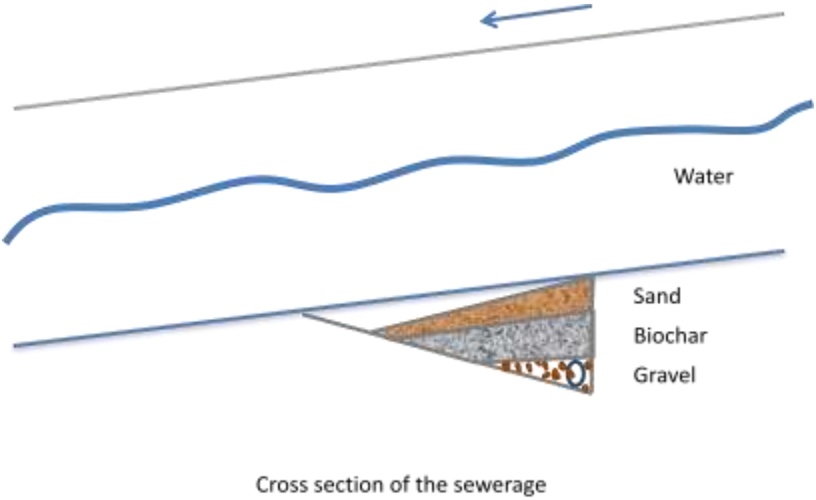


Picture 86 Details of perchigation 3

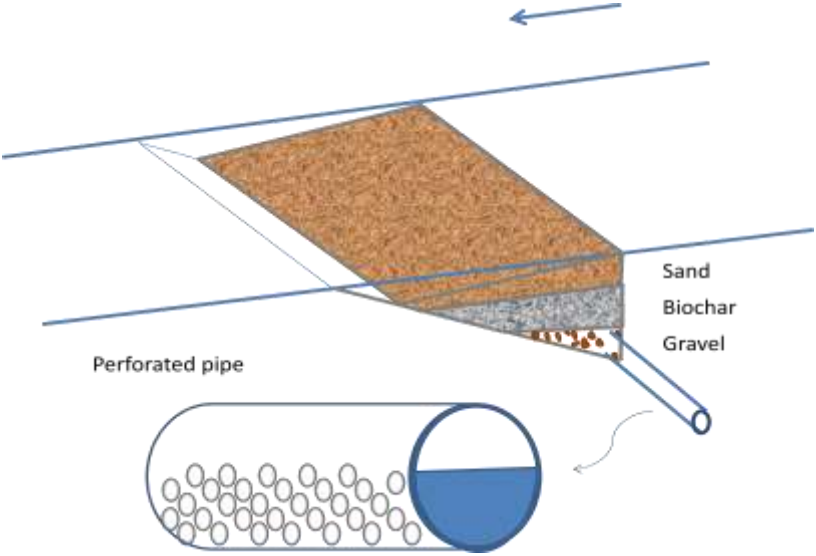
Sewagigation

Under normal circumstances, sewage water is drained away from homes and left in water bodies. There is always a demand for water for various purposes. Water resources are becoming polluted and this is affecting aquatic ecosystems. Many cities are already facing water shortages to meet the demands of the people. Water is also required for greenery too.

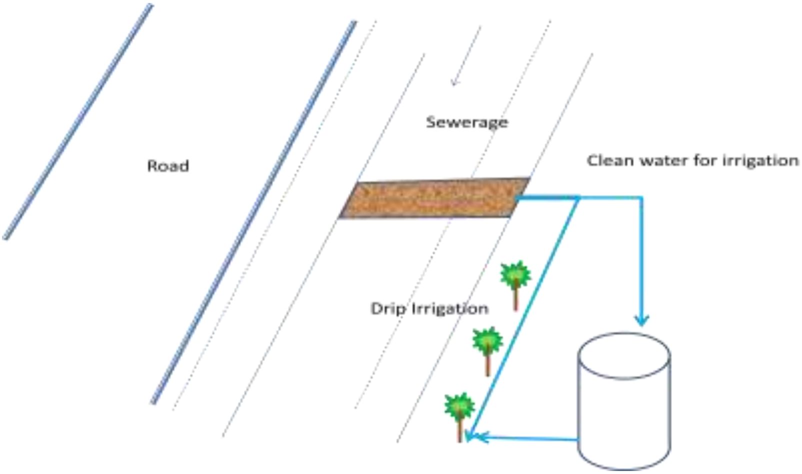
Sewagigation is a sewerage design using biochar to filter sewage water to irrigate plants and to store water for multiple uses other than drinking.



Picture 87 Details of sewagigation 1



Picture 88 Details of sewagigation 2



Picture 89 Details of sewagigation 3

Agriculture

☐ Biochar application in agriculture – germination and crop production

Biochar is a useful resource in diverse agroecological systems. Biochar can increase crop-land use efficiency, reducing the land area needed for crops. It improves the fertility of all types of soils — acidic, alkaline, and degraded and increases agricultural productivity. Biochar increased corn yield in American farm trials by 20% (Hawkins et al., 2008). Biochar increased sweet corn yield by 10% and tomato yield by 22% (Morse, and Stevens, 2006 in Hawkins, et al., 2007). The gross cultivated area increases as more corps cultivated each year. The vulnerability of crops is reduced with the use of biochar.

Picture 90 A small farmer applying biochar compost in his field

Biochar protects and supports the growth of roots. It increases the available nutrients for plant growth, resulting in yield increases. If all soil nutrients are available in plenty and the soil condition is healthy, there is little variation between the biochar and control plots.

Differences are higher in less fertile and degraded soils. Biochar is good for all types of soils, because the fertility of soils varies across time and space. The air, water, nutrients in addition to the soil microbes thriving in the soil through biochar are useful for plants and the environment.

It has been observed that 1 kg to 3 kg of biochar applied to every 1 m^2 field area gives good application results. Compost and other nutrients should be added to the field, as per regular practice for most crops.

While biochar amendment has multiple benefits as described above, researchers have reported nitrogen immobilization and yield reduction when biochar is applied to the soil without fertilizers (Gundale and DeLuca, 2007; Deenik et al., 2008). This is because biochar adsorbs the nitrogen available in the soil and renders it temporarily unavailable to the crop plants.

Initially, more nitrogen should be added (1.5 to 2 times) than what is applied regularly; green mulch / composts / FYMs, etc., are the most preferable sources of nitrogen.

Traditionally, people have used biochar and ash in their fields. This practice exists all over the world. There is a need to recognize the value and create awareness on biochar.

Germination

When using biochar, farmers spend less on seeds as the germination percentage increases and seedlings are protected. It is observed that the chances of seeds germination are 20% to 30% higher in the soils with biochar compared to control soils.

Picture 91 Control pots with only soil and pots with soil plus biochar

Initially, one needed to add more nitrogen to the soil with biochar, as some nitrogen is absorbed by the biochar and some is used by the living microbes in the soil. Biochar slowly releases nitrogen into the soil for the plants to absorb.

Note: The above comments are based on physical observations in an open environment. No pesticides or fertilizers were applied to the soil.

Paddy

Paddy receives more criticism than any other crop as a contributing factor for global warming through Methane and Nitrous oxide emissions, extensive and intensive use of water, contributing to soil alkalinity in semi-arid areas, use of heavy fertilizers, etc. The application of biochar to paddy fields will lessen all of these impacts, including methane and nitrous oxide emissions. With biochar, paddy grows well, higher tillers, better roots, and has higher yields.

Biochar as a byproduct from pyrolysis of rice husks, which is a very good source to apply back to the paddy fields.

Picture 92 Biochar compost application in paddy field

Beans

In the experimental plots, after sowing beans and observing them one week later, it was seen that nine sprouts had emerged from the biochar pot and only eight sprouts had emerged from the control soil pot of the total 10 bean seeds sown in the pots. The plants are taller and are healthy in the biochar pots compared to the control pots.

Six bean seeds each were planted in the control pot with red soil and in the pot with a mix of red soil and biochar (30% biochar by volume as compared to the red soil used). Three beans have germinated in the control pot and six beans have germinated in the pot with a mix of red soil and biochar. Other results are visible in the pictures presented.

Picture 93 Fast and healthy growth of bean saplings in biochar pots (right side)

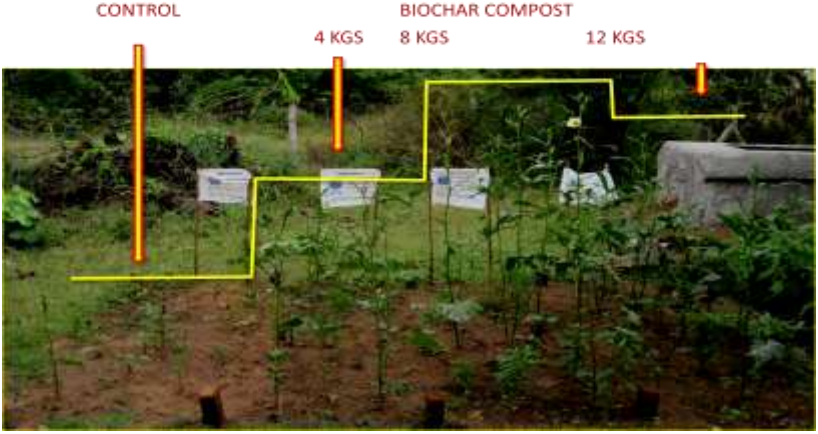
Field trials

Biochar application in field trials impact on soil and crop

In the four habitations of Devaruppala Mandal, Telangana State, India, field trials were conducted over three years. In Kharif (2009), only one cotton crop was monitored. In Kharif 2010 and 2011, cotton, sesame, paddy, green gram, and mango plants were monitored. In Kharif (2011), five crops were monitored. The field size varied from 5x5 m to 10x10 m in the case of agronomic crops. For the field trials, differences in phenological properties due to biochar compost amendment were monitored approximately every 15 days (6 to 11 visits per season). The only agronomical advice given to farmers was on micronutrient deficiencies based on soil tests. Farmers used their usual seeds instead of special varieties to ensure that the results were appropriate for the region. Application of pest control methods was left to the farmer's discretion.

Picture 94 A healthy cotton field, with biochar application

Biochar and biochar compost analysis was conducted using proximate analysis (method IS-1350-1984). Soil samples were collected for standard soil testing. Various parameters such as soil texture, organic carbon, pH, salt, major nutrient phosphate (P_2O_5), and potash (K_2O), and micronutrients, zinc, iron, manganese, and copper were analysed. Additional analysis of CEC was conducted from 2011 to 2012 to determine the impact of biochar amendment.



Picture 95 A trial plot showing differences in growth, with variable application of biochar compost.

Picture 96 Healthy greengram pods, where biochar compost was applied

Biochar and soil

In 2009 and 2010, biochar compost amendment did not have any significant effect on soil properties except for iron and manganese. During the first year, soils with biochar amendment had consistently higher iron and consistently lower manganese levels than control soils. It is possible that the iron in the biochar was exchanged with the manganese in the soil, but further studies are necessary to understand the mechanism behind this effect. Biochar compost amendment also increased the microbial population of the soil significantly. Comparison of the bacterial count of the biochar and control samples showed up to 34 times the bacterial count in soils amended with biochar compost—a 3,400% increase.

Organic carbon results were given only as a level (low, medium, and high) by the soil testing lab, which did not offer specific measurements. According to these measurements, organic carbon levels showed a change in only one case. In all other samples, the organic carbon levels remained the same (low). However, it is likely that a more accurate analysis would show a considerable difference in the total soil carbon concentration due to higher microbial activity in the soil, as organic carbon is likely consumed by these microbes.

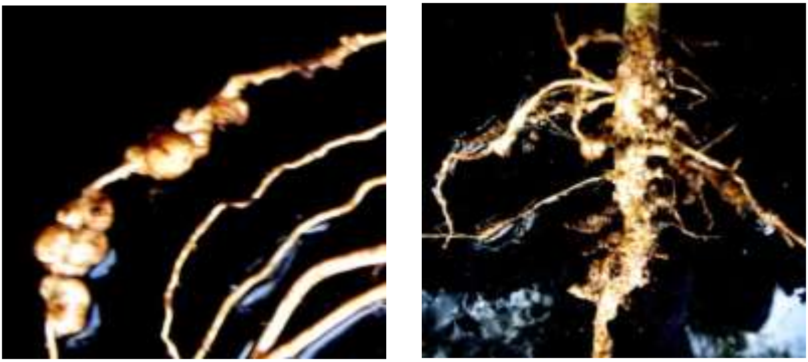
Over the three year period, all soil properties except pH showed significant changes. In both biochar amended and control soils, salt, manganese, and potash content showed consistent increases while phosphate content decreased. There was no significant difference between treatments in the same year, and changes in biochar amended and control soils were similar in all properties except potash content. This suggests that the biochar compost added potash to the soil, which is in accordance with research that has shown biochar to be a source of potassium (Sarkhot et al). The increase in salt and manganese was likely due to the addition of salt and manganese through irrigation water. This explanation was supported by the water analysis carried out in 2011 to 2012, which showed electrical conductivity values ranging from 760 to 2,520 micro mhos/cm. Manganese was probably added by the biochar compost, as the analysis of biochar compost showed 6.54 ppm manganese content.

However, the decrease in the phosphate content showed that additional phosphate fertilizers would be needed to maintain soil productivity. The salt build-up observed over the three years also suggests that the practice of flushing the biochar with water would be beneficial in this region.

Biochar and crop

Biochar amendment resulted in consistent and statistically significant increases in plant height and in the number of flowers and fruits of the cotton crop. During the Kharif 2009 season, increase of 5%, 49%, and 213% were observed in plant height, number of fruits, and flowers respectively due to biochar amendment. The number of flowers and fruits showed statistically significant differences. During the Kharif 2010 season, all three parameters exhibited statistically significant differences. Average plant height increased up to 25%, the average number of flowers increased up to 55%, and the average number of fruits increased up to 60%. Positive results were confirmed in qualitative assessments by the farmers. When coupled with lower cost of fertilizers and pest control, as indicated by the farmers' assessments, it is confirmed that soil amendment with biochar has considerable ecological and economic benefits.

Picture 97 The growth of roots and the total biomass is very high with the application of biochar compost



Picture 98 The rhizobium growth in plants was found very high with application of biochar

Picture 99 With application of biochar compost the growth in Okra is four times more compared to control soil,

Similarly, sesame crops saw up to 22% increases in height and up to 40% increases in the number of branches. The biochar amended paddy crop saw an increase of 22% in tillers per plant. The height of the plants was smaller, but the difference was not statistically significant. The number of tillers is an indicator of the yield of paddy rice, and it shows that biochar compost was likely to increase yield significantly. Accordingly, paddy farmers reported a 20% increase in their yields.

In 2011, the biochar amendment resulted in a 27% increase in plant height and up to 19% increase in the number of tillers per plant in the paddy.

At the GEO Research Centre, the biochar compost was applied at optimum rates 20 kgs of biochar compost per 3 m x 1 m plot. This biochar compost was applied to the plot in two phases: in the first year, 12 kgs of biochar compost were added and okra was cultivated. On the same plot, 8 kgs of biochar compost was applied the next year and cluster beans were cultivated. A record increase in the growth and yield of cluster beans was observed. The plant height increased by up to 82%, the girth of plants increased by up to 125%, and the number of beans per plant increased by up to 260%. The differences were statistically significant for all three parameters. The maximum height attained by one of the plants was 11.5 feet, which is a record growth of a kind never witnessed by local farmers.

Farmer's assessment

One of the farmers, Mr. Kailasam, reported that biochar amendment resulted in greener rice plants, 5 to 10 more tillers per plant, longer rice pinnacles (up to 9"), stronger grains, and 20% more grains. He also reported that biochar amendment costs only half that of chemical fertilizer. Biochar amended soil had more moisture and it did not have any termites. According to this farmer, plants grow quickly and get attacked by pests when treated with chemical fertilizer; with biochar compost, plant growth is slow but there are fewer pests.

Another farmer, Mr. Komuraiah, reported that biochar amendment resulted in taller, greener plants, smoother leaves, darker soil colour with better soil structure, and fewer pests and diseases. He reported that yield increased by 10% and the cost of biochar was half that of chemical fertilizers. He said that biochar compost is very good for nurseries and he would like to try biochar application on the whole field. He would also recommend biochar compost to others.

Picture 100 A field trial plot with application of biochar compost

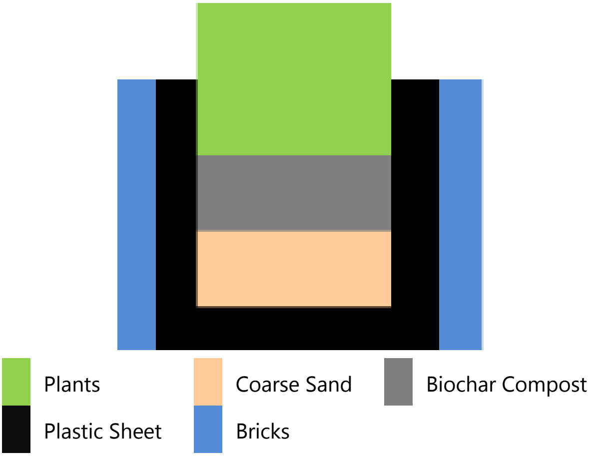
Urban gardens

Biochar gardens

Biochar usage in urban gardens for greenery

Biochar is a very useful medium for creating gardens, including rooftop gardens, kitchen gardens, mobile gardens and vertical gardens. In natural environments there are various systems for soil management, but in urban areas there is very little natural soil and space. Biochar gardens are highly suitable in small spaces, because of the inherent properties of biochar compost to sustain more plants per given area. Tomatoes, brinjal, beans, ginger, garlic, onions, chilies, and green vegetables have all been successfully grown in experiments.

Picture 101 Details of a roof top garden



Picture 102 Details of roof top garden – cross section

There are many advantages of biochar gardens:

- As biochar compost is light, its weight does not have much impact on buildings and other structures.
- Biochar gardens present low-cost solutions for efficient use of urban spaces.
- Biochar gardens complement the need for more vegetables growth.
- Fresh and nutritious food is available close to homes.
- Economic savings are acquired through access to self-grown food.
- The water retention capacity of the biochar compost makes it ideal for conservation and the use of the scarce water in urban areas.
- Biochar gardens present an efficient solid waste management option by composting organic waste

- Biochar gardens provide insulation
- Rooftop gardens provide entertainment, social, business, and cultural activity spaces.
- Biochar gardens can provide walkways, which are beneficial from a health perspective, as they are great places for exercise and mental peace.
- Gardens have inherent aesthetic value.

Biochar mobile gardens

Biochar mobile gardens are the concept of using biochar compost to grow plants on mobile platforms. The gardens can also be grown on or inside vehicles. These gardens add vibrancy to the urban environment. The main advantages are as follows:

Picture 103 Biochar compost can be used flexibly in any container for growth of plants

- Biochar compost is a lightweight material, so it is convenient to adopt in mobile gardens.
- With very little biochar compost by volume, a high density of plants can be grown.

- Mobile gardens freshen the air; aromatic plants would emit nice smells. Mobile gardens are a cheap, better option than air fresheners / other scents, which can be harmful.
- Biochar mobile gardens conserve water; very little water needs to be applied to plants.
- Biochar mobile gardens have considerable aesthetic value.
- Biochar mobile gardens make vehicle interiors cooler on hot days.

Picture 104 Mobile gardens as an example using biochar compost plants are grown inside a car

- Growing food and lettuce plants would be of great value for consumption.
- Biochar absorbs carbon dioxide and other harmful gases released from closed spaces.

Sanitation

Urinals

Biochar is applicable for human and animal waste management, converting urine, excrement, or dung into fertilizers and resulting in emissions reduction.

Biochar use for sanitation – urinals maintenance and cleaning

Biochar can be used to trap the nitrogen from urea in urine and other useful elements. Simple biochar urinals can be created for this purpose. Biochar treated with urine is useful in improving the quality of soils and enhanced crop production with enzymes and urea, and in addressing global warming by reducing NOx gas emissions. Biochar use results in savings on artificial fertilizers and keeps toilets clean and odour free.

The production of fertilizers requires lots of energy. In many countries, natural gas is used to produce urea in large quantities. The demand for natural gas is growing and energy prices are ever increasing. The complex fertilizers used to improve the fertility of soils are also contributing to soil alkalinity.

Using biochar to trap nitrogen and other elements is a great opportunity to find solutions for many problems. Urine is a great source of nitrogen, phosphorous and potassium and has far greater value than faeces. For example, in India an average person's urine has the following units of values:

Table 13 The average value of human urine per person per year

	Urine (kgs)	Faeces (kgs)	Total (kgs)
Nitrogen (N)	2.4	0.3	2.7
Phosphorous (P)	0.3	0.1	0.4
Potassium (K)	1.1	0.4	1.5

Source: Human urine harvesting for food security, Prakash Kumar, SEI-UNICEF.

Two prototype biochar urinals—PVC urinal and clay pot urinal—were designed by the author.

Upon saturation, pots of urine with biochar can be collected and spread on the soil. Pots containing biochar plus urine can also be disposed of by breaking them into smaller pieces in the soil, as the pottery shards also benefit the soil.

The clay pots were filled with biochar to collect urine. It is best to collect fresh urine from the source and immediately saturate with biochar so as not to lose value, rather collecting urine separately and later saturating it with the biochar.

This experiment involved two children (ages 4 and 6), who were instructed to urinate in the clay jar. The clay jar is 6 inches in diameter and 10 inches in height with very fine holes of 2 millimetres in diameter at the bottom. The jar was filled with biochar—a byproduct from the biomass stove. These jars were kept in the washroom for the children to use. Each jar absorbed about 200 ml of urine easily without any leakage from the bottom. The total urine collected per day was around 500 ml. After about 10 days, the jars smelled like urine, indicating that the jar was saturated with urine. The jar was kept aside in a cool place to dry.

Picture 105 Simple biochar urinals

The urine odour was reduced as a result of the biochar used. Using biochar, one can easily design urinals free of smell, instead of using air fresheners (naphthalene balls, scents, phenyl, etc.) in washrooms. Schools are the best places to collect urine from children, which is beneficial

Picture 106 Right side: Biochar + Urine + soil | Left side: Biochar + soil. Right side darker green leaves in comparision (Bean seeds were planted in pots , 10 days old saplings)

because children's urine is more likely to be free of disease, and children use fewer medications.

Cleaning

Biochar is a useful medium for cleaning. Kitchen dishes can be cleaned using biochar powder (rice husk biochar is ready to use). Oily matter and bad smells are completely removed, and dishes turn out very clean and ready to reuse. Very little water is required to rinse dishes cleaned with biochar.

Picture 107 Rice husk biochar is used for dry cleaning of plates after eating

After cleaning dishes, the biochar attains increased value as a soil amendment, as the food, oils, etc., embedded in the biochar becomes feed for soil microbes.

Health and Food

There is a need to develop biochar health products and discover more applications for common use.

Biochar use for good health and environment such as food, teeth cleaning, etc

Food

In the past, means of transportation were slow and there were no vehicle-based refrigeration systems. When people carried raw meat long distances (e.g., two to three days to reach their destinations), they carried the meat with biochar pieces in it. The meat remained relatively fresh in the presence of biochar and there no bad smells were released (Carbon dioxide, Methane, etc.), which would have attracted attention or wild animals en route. Keeping some pieces of biochar in modern refrigerators is always recommended to keep food items fresh and reduce odour. In another use, if by mistake too much salt were added to a curry, charcoal pieces would be immersed in the sauce to reduce saltiness.

Picture 108 The biochar formed on the rotis while baking

Teeth cleaning

In many parts of India, people still use biochar from cook stoves to clean their teeth. Cow-dung cake charcoal is preferred, freshly taken from the stove and quenched with water. This biochar not only cleans teeth but, removes bad odour through absorption. Biochar toothpaste is unlike mint and other strong-flavoured toothpastes, which dominate with their own smell rather than freshening the mouth. Many types of tooth powders can be created by blending biochar powder with, rock salt powder / crystal salt powder, Epsom salt, mint, clove oil, eucalyptus oil, etc.

Other uses

- As tablets for gastric problems
- To remove the impact of poison from the stomach and intestines
- As first aid applied to snake or scorpion bites
- In mattresses and pillows for health and emissions reduction
- In bath soaps, shampoos, and creams
- As a feed additive for farm animals to reduce methane and carbon dioxide emissions
- In the storing of eggs on poultry farms

There is no such thing as waste.

Green Buildings

🗒 Biochar use in green buildings as biochar bricks, etc.

There are many advantages of using the biochar as a component in green buildings for clean indoor air. Biochar can remain in soil for 1,000 years or more. Biochar has been found intact in earth walls of over 100 years old. It can be mixed in different proportions with sand, cement, earth, sawdust, and other suitable materials to produce bricks, panels, and blocks. The percentage of biochar in different products can be decided based on the purpose and ultimate product properties. Biochar use makes building walls light and insulated.

Picture 109 The biochar used in the pots of indoor plants, freshens the interior space

The biochar produced from different biomasses, temperatures, and processes have different properties. For example, coconut shell biochar appears crystalline, rice-husk biochar has high silica content, etc. The highly porous surfaces of biochars have been shown to adsorb N_2O, CO_2, and CH_4 (Van Zwieten et al.). When used in green buildings, biochar absorbs some GHGs. After reaching landfill sites, biochar from green buildings reduces GHG emissions and also prevents landfill leachets. Biochar can be used as a screen for air purification in buildings. Biochar regulates humidity indoors and absorbs emissions from indoor washrooms. Considering the life, source, and properties of biochar, it is a means of carbon sequestration. Biochar also brings other benefits: temperature is regulated through insulation and reduces construction costs. Biochar is resistant and repels termites and ants. Biochar is the source of negative ions, prevents oxidization, emits infrared radiation, and dissipates electromagnetic fields from many electronic and electrical devices in a house, improving household living conditions. Considering the properties of biochar in improving indoor air quality and benefits to the user and the environment, biochar can be used in all green buildings as needed.

Picture 110 Biochar bricks and the building where biochar bricks were used in construction

Biochar bricks

Biochar bricks are made using, rice husk biochar (a byproduct from rice mills), cement, and sand. With different ratios, bricks were made from the above three materials. These bricks are lightweight and especially suitable for multiple-storey buildings, particularly for inside walls, walls for top floors, and walls between beams. Biochar bricks are ideal for bedrooms, as they remove obnoxious smells from attached washrooms, paints, moulds, etc. They are suitable for construction around plants and pathways. Biochar bricks provide insulation, keeping buildings cool in summer and warm in winter. They are resistant to termites. In addition, when buildings are demolished, the waste material from biochar bricks would benefit the soil and sequester carbon.

Table 14 Three types of bricks were prepared using biochar for testing

Biochar bricks (BB)		
BB1	BB2	BB3
Rice husk biochar: 6 kgs Cement: 3 kgs	Sand: 14 kgs Rice husk biochar: 2.5 kgs Cement: 2 kgs	Sand: 14 kgs Rice husk biochar: 1 kg Cement: 1 kg
Note: Dimensions of each brick are: 11.5 x 7.5 x 6 (in inches)		

Sustainability of biochar

Sustainable sources of biomass are not always available for conversion into biochar, although biomass is available from various sources in large quantities. Worldwide, crop residues produced amount to ~4x10^9 Mg/year[15]. Soil organic matter is required as a regular input for soil management, a majority of which comes from crop residue, mulch, composts, etc. In India alone about 800 million tonnes of crop residues are produced annually.

There are no stringent rules in the management of crop residue. Some residues are burnt by farmers. In the process, considerable smoke is generated

☐ On sustainability of biochar production and use; biochar use in developing countries

Picture 111 Biochar compost can be applied for all types of soils

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[15] http://www.fao.org/ag/ca/Carbon%20Offset%20Consultation/CARBONMEETING/3FULLPAPERSBYCONSULTATIONSPEAKERS/PAPERLAL.pdf

and valuable biomass is wasted. For the recommended biochar application of about 10 to 30 tonnes per hectare (sometimes even more) and for large-scale applications by millions of farmers, the presently available biomass is not sustainable. The approach of designating specific land for biomass production for large-scale commercial biochar production should not be encouraged, because this approach competes with limited land resources. To import biochar from any other country is also unsustainable and unjustifiable. Biochar is not an exclusive product for soil application; it is widely used for various applications and a great deal of biomass is already being converted into biochar for such uses – especially for fuel. This new demand for biochar as a soil amendment en masse adds to existing demands.

Farmers need open source biochar production technologies and standards.

Biochar for developing countries

A major concern in a country like India is that 60% of farmers live on less than one hectare of land[16]. Farming is not sustainable for a majority of small and marginal farmers in parts of India. Over the years, they have been dependent on government policies and subsidies for power, water, seeds, fertilizers, minimum support prices for produce, etc. It is necessary to liberate farmers from this dependency system.

Another advantage of biochar is that it can be used in all types of agricultural systems (organic, chemical, permaculture, mixed farming, natural farming, biodynamic agriculture, Homa therapy for agriculture, zero tillage farming, etc.) Biochar application in small amounts will not burden the farmer. A farmer could produce 100 kg to 200 kg of biochar from crop residue annually from one hectare of land, which would otherwise be burnt in the field apart from the use of crop residue for mulching, composting, and fuel. Biochar added to the soil in large quantities reduces available nutrients to the crops initially, unless it is added along with extra compost and fertilizers. But by adding biochar in small quantities, farmers need not worry about the high costs of extra compost and fertilizers that would have been needed, if large quantities of biochar were added at a time. Over a period of time, biochar matures and adapts to the local soil conditions. For small and marginal farmers, application of biochar over a number of years is more convenient. They can convert some

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[16] http://www.usaid.gov/indiatrip/usaid_partnership.pdf

of their crop residue into biochar and mix it with FYM for application. Biochar will remain in the soil for more than 1,000 years, so one need not hurry to achieve maximum yields immediately.

Picture 112 For sustainability of agriculture and food production, biochar is an important adaptation

The best biochar technologies and products are only adoptable by big farmers. Agriculture has become a high input and dependent system, which is hardly sustainable for small and marginal farmers. Biochar products and technologies available on the market are not accessible to farmers, as they are patented and come at a high cost. Therefore, the industrial approach to biochar production is not a feasible option in many developing and poor countries.

GEO Research Centre

A place for microbial biodiversity as a source for innoculation with biochar

The GEO Research Centre (GEO RC) was established in March 2010 on a piece of land in Peddamaduru village, Devaruppala Mandal, Telangana State, India. It has served as a centre for training sessions and demonstrations of newly developed technologies, and is a site for biochar and biochar compost production.

Picture 113 Biodiversity as seen at the GEO Research Centre

The centre has a biodiversity with more than 200 plant species, on half-an-acre of land. This serves as a source of microbial culture for biochar compost and a low-cost solution for preserving and enhancing local soil microflora and microfauna. The soil at GEO RC has not been tilled in the last 30 years, and there have never been any pesticides or artificial chemicals applied. Soil from here is added to the biochar compost. The centre also boasts of a stoves museum with 50 stove designs developed by the author. There is a need for many such centres to support indigenous microbial life for the present and the future of the earth.

Cost of biochar

☐ On the reasons for variation in the cost of biochar and biochar blends produced

For the user, the cost of the application of biochar compost is not too high, if produced by independently using locally available raw materials. Incremental application allows for more sustainable use of biomass and avoids the possibility of damage to crop productivity due to an overdose of biochar compost.

Although farmers were happy with the biochar compost application results during field trials, it is difficult for them to adopt application on a large scale because of the high cost of biochar production technologies. The cost of purchasing biochar is relatively high, as it is also used for various other purposes. Efficient, cheap, and convenient technologies are not available. Because of the complexity of biomass (types, values, size, shape, density, etc.) converting it into biochar is difficult by any single design, so there is a need for many different biochar production designs. Most wood charcoal is produced by earth mound kilns, but for the conversion of crop residue this technology is inconvenient. Not all types of biomass are easily convertible into biochar. Presently, the use of traditional systems to convert crop residue into biochar necessitates efforts that go well beyond the cost of buying the same quantity of charcoal made from wood in earth mound kilns. Current technologies are also inefficient for every 100 kg of biomass the average biochar yield is only 20% to 30% of the weight of the biomass used. Moreover, the type of biomass used and the process and temperature at which the biochar is produced are important to qualify the result as a biochar product. Biochar production technology designs should be cheap, mobile, and convenient for in-situ production.

If a farmer is using own raw material, one could produce biochar compost at a cost of Rs. 5 per kilogram. On a no-profit basis, biochar compost can be produced by others at a rate of Rs. 15 per kilogram. The retail price of very good biochar is Rs. 25 per kilogram. This analysis is based on the author's observations in different parts of India. Farmers should be encouraged to use biochar in their fields on a trial basis and results should be compared with control plots. They should be able to decide on the quantity required. The cost and quantity of biochar required are relevant considerations.

Biochar fines, a byproduct of the stove cooking process, have no cost at all. Larger charcoal parts are available for US$150 to 250 per tonne in developing countries (Lehmannn and Joseph, 2009). The deployment of biomass pyrolysis systems can create new local businesses and job opportunities, and can and raise incomes in rural communities (Okimore et al., 2003 in Hawkins et al., 2007). An industrial tree plantation processing 368,000 tonnes of biomass provides jobs for approximately 2,600 people (Okimori, 2003 in Hawkins et al., 2007). On the global market, the average price of pure biochar is $1 per 20 kg; smaller quantities have a higher price—up to $5 per 20kg. Larger quantities have prices as low as $0.60/20 kilogram (Baranick et al., 2011).

Fertilizer requirements can be reduced by 10% to account for improved efficiency in the use of fertilizer by crops (Gaunt and Lehmann, 2008). When used as a supplement to fertilizer or compost, biochar can reduce inputs of these products by 25% to 30% (Baranick et al., 2011). Morse and Stevens (2006) mention a 37.5 kilogram N/ha reduction in nitrogen application requirements for Irish potatoes (in Hawkinset et al., 2007) with the application of biochar.

Livelihoods

On the impact of biochar on livelihoods

Biochar also addresses livelihood needs through enhancing the following sources of capital. Biochar and allied sectors enhance the living conditions of rural families by converting biomass into biochar and through the use of energy. Income is generated from sales and wages from production and processing of biochar into biochar blends. Likewise, carbon offset payments support the use of biochar and clean cook stoves. Carbon offsets should be optional and should not be the main goal in promoting biochar.

Natural	•Agriculture productivity increase •Low input agriculture
Social	•Local jobs and equity •Local enterprises
Human	•Least skills •Biocharculture
Physical	•Local technologies •Low energy
Financial	•Low carbon economy •Low cost
Environment	•Carbon sequestration & energy security •Mitigation & adaptation to climate change

Picture 114 Biochar adaptation has multiplier effect on livelihoods sustainability

Picture 115 Mr. Chunbad's family cultivated vegetables using biochar compost

Bundelkhand area in central India is one of the economically most backward areas in India. Lack of resources and infertile lands are some of the reasons for underdevelopment in the region. EFICOR is an NGO working for the development of poorer communities in parts of India including this area. The author has trained the EFICOR staff on biochar compost production and application for soil fertility improvement. Mr. Chunbad is a poor farmer from Bundelkhand area. He is having very little agriculture land. In his family there are seven members including his 5 children. He used to cultivate Horse gram and Pigeon pea and was getting an income of Rs. 10000 after investing Rs. 5000 for inputs. This income was not sufficient enough to maintain his family, therefore he used to migrate for work to the cities or towns like Delhi, Chitrakoot and Allahabad for 6 to 8 months in a year. With the support of EFICOR, last year he applied biochar compost in his field and started cultivating vegetables such as cabbage, cauliflower, chillies, brinjals, tomatos, okra, etc. This family could earn six times the previous income i.e., Rs. 60,000 by selling vegetables and the head of the family is no more migrating for livelihoods and their children are going to school.

Challenges

Badly implemented biochar systems could reduce biological diversity. Such systems might contribute to large-scale land use change for biofuels. Pollution can be released if less efficient biochar production methods are used. There is considerable potential for contamination from badly designed industrial biochar production, resulting from poor choice of feed stocks or hazardous materials. Biochar that is not well matched to soils (particularly if it is the wrong pH) could temporarily reduce crop productivity or alter the biodiversity of native soils. Biochar could favour some soil microorganisms over others with potential negative impacts on native biodiversity. Further research is needed before recommending biochar for various applications.

Challenges of biochar for adaptation

Picture 116 The charcoal fines from charcoal production areas is a useful resource for application as biochar

Black carbon entering the atmosphere from various sources, including during biochar production, application and from wind erosion, can have impacts that are more serious than carbon dioxide emissions. Lower soil albedos might accelerate global warming, especially when biochar reaches the ice sheets in the polar regions. In this regard, precautions should be taken at the time of production and application.

There is disagreement over whether biochar should be applied in fine powder form or in pieces. If biochar in fine powder form is applied, there are some immediate benefits, particularly that it would spread to a larger area in the field. However, during preparing, in the application process, and following application, the chances of this biochar reaching the atmosphere in the form of black carbon are increased. Moreover, a very small piece of biochar could create an environment within and around it that is more vulnerable to soil life, compared to the environment created within and around a large piece of biochar. It is difficult for a piece of biochar to become airborne; soil can easily hold a piece of biochar and prevent it from eroding by natural forces. It would take hundreds of years for human and natural factors to reduce the pieces to a considerably smaller size. Rather than achieving desired results immediately, considering the impacts of airborne black carbon, one can always choose to apply pieces of biochar rather than fine biochar powder to soils as an amendment.

Civil society debate

🗒 Civil society debate on the ecological impact of biochar sector

Civil society has begun to debate the use of biochar for soil amendment to achieve increased soil fertility and to reclaim degraded soils. Large scale application of commercialized biochar products is not considered a positive development. Biocharculture integration into traditional and local practices should be encouraged. Encouraging local communities to produce and use biochar with locally available raw material is considered sustainable. If this strategy is adopted, there is a need for capacity development and empowering processes for local communities as a movement. The standards of biochar vary locally based on the availability of raw materials and soil microbes. The civil society will continue to fight against all major industrial biochar production processes, having declared a moratorium on all geoengineering methods.

Awareness

On the need for creation of awareness on biochar

The value of biochar is being discovered and application methods are evolving. Naturally, there is apprehension when there is incomplete understanding and limited knowledge. Thus, mass awareness-raising regarding biochar, including the pros and cons, is required among various stakeholders. The traditional best practices of biochar application should be continued. Farmers should also adopt new and appropriate technologies to improve soil fertility and sustainability.

Picture 117 Creating awareness on biochar is important for large scale awareness.

The author has created mass awareness through field trials; demonstrations at the GEO Research Centre; collaborative activities with other organizations, agencies, institutions, and universities; information disseminated through weblinks online in the form of presentations, photos, videos, and podcasts; and participation in conferences and workshops at various levels.

Achievements

On the achievements of introducing biochar to the farmers

This author's work on biocharculture since 2005 is pioneering. Emissions reduction was also achieved through a reduction in the use of chemical fertilizers, insecticides, soil emissions, etc. A majority of the farmers who participated in studies remained in the field trial, indicating satisfaction with the results.

As part of outreach activities, biochar compost samples were sent to 10 eminent universities and research institutions for independent analysis and field trials. Through the assistance of other non-governmental organizations and agencies in parts of India and abroad, nearly 5,000 people were directly reached. Tribals on the fringes of the Nallamalai Forest in Andhra Pradesh, India have acquired biochar compost on a large scale for their horticultural crops.

The study of soil properties and crop growth across various crops and applied by multiple farmers shows that soil amendment with biochar compost results in many beneficial effects, including improvement in soil productivity and soil structure, increased crop yields, decreased incidence of insect pests, and decreased cost of fertilizers. For example, cluster beans showed up to a 260% increase in the number of beans per plant. Increases in plant height and plant girth show that the biomass production also increased, which would offer further opportunities for carbon sequestration and biochar production and increased availability of biomass for other uses (e.g., cattle fodder). Biochar amendment is also known to decrease GHG emissions from soil. Replacement of chemical fertilizers and the addition of biochar in soil, which is a highly absorbent material, is also likely to reduce losses of nutrients through leaching and to improve the quality of ground water.

Picture 118 Unbelievable plant growth rates have been achieved with biochar compost application to the soil

Moving Forward

🗒 On the ways and means of sustainably using biochar for development and environment

Globally, many countries are involved in research, development, and application of biochar. Integrating biochar production and application locally is likely to be a more sustainable practice than large-scale, centralized production and dissemination. Such practices should be encouraged and given top priority. In addition, there is a need for further research for the development of biochar plus products. At the same time, ongoing traditional biochar best practices should be recognized and improved. In this regard, the roles of the scientific community, public polity, civil society, mass media, and other stakeholders are very important.

A study is required to document traditional biochar practices in different parts of the world. We should strive to know more about indigenous, traditional biochar practices and learn low impact sustainable biochar methods. It is necessary to find ways to improve existing practices for sustainability and adaptation by stakeholders in different parts of the world. While facilitating low-cost, efficient, adoptable technologies for conversion of biomass into biochar, stringent laws can be introduced to prevent the exploitation of biomass and to ensure efficient energy use and biochar production.

Inefficient biochar production technologies should be phased out. Biochar as a byproduct should be given top priority for usage, rather than producing biochar exclusively. There are many biochar sources, including stoves, gasifiers, thermal power plants, etc., that can produce both biochar and energy.

Having found a new opportunity in biochar, many private companies have emerged to sell it as a product. Biochar products (blends) being promoted under different names by various companies cause confusion. Standardization of terms should be facilitated by a common agency, because there are more than 50 terms in use to describe biochar products. Companies are conducting and publishing research on biochar compounds and the results of product application on crops. Results are very encouraging, but the composition of biochar products is secretive. The components of biochar products should be revealed in the common interest. All biochar products or blends should be made open source along with documentation of their results. The efforts companies, agencies, organizations, and individuals involved in research should be compensated by either national or international agencies. All the biochar technologies should be declared as open knowledge. Standards for ethical biochar production and use should be developed. Biochar standards testing labs should be established for the regulation of spurious products. Sustainable methods to characterize biochar that are accessible to small farmers are required. There is a need to standardize biochar products for application to different types of soils and crops in different geographic regions and conditions. There is also a need for research and awareness-raising about biochar and its uses.

About the author

The author is a pioneer in reintroducing the values of biocharculture in parts of India. He had trained thousands of people on biochar from parts of India and several other countries. He had been working with farmers on biochar production and application for a decade, and is involved in facilitation, design of biochar blends, application methods, and monitoring of results in the field. The experiments outlined in this study were designed, implemented, monitored, and analysed by the author.

The author understood the value of biochar through field observations and experiments conducted in parts of India. Farmers have adopted biochar in their soils and have grown diverse crops with enhanced yields, and they are very happy. The farmers were trained to make biochar compost using locally available materials.

The author encourages stakeholders to adopt sustainable biochar production and application systems and has designed biochar production technologies that are low-cost and efficient. He also designed low cost highly efficient 50 good stoves that produce biochar as a byproduct. On the whole, he has identified the value of biochar and broadened the scope of biochar to “biocharculture.”

All of the author’s work is declared as “Open Knowledge” and published extensively on blogs and websites. Every day the information is accessed by at least 2000 people from all over the world.

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[17] MetaMeta provides research and consultancy services in water governance, and offers specialised communication products geared to the international resource management & development sectors. www.metameta.nl

[18] 3R stands for Recharge, Retention and Reuse of Groundwater & Rainwater, which is involved in sustainable and innovative management of water resources, in relation to development as well as adaptation to climate change. www.bebuffered.com

I express my sincere thanks to the farmers' community, the people who believed me and adopted the biochar for soil amendment and got very good agriculture production results. I would like to thank all the people who supported me over a decade in contributing to the understanding of biochar as a resource. I consider them as the "Earth Leaders" for their role in dissemination of biochar knowledge in parts of the World.

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Weblinks

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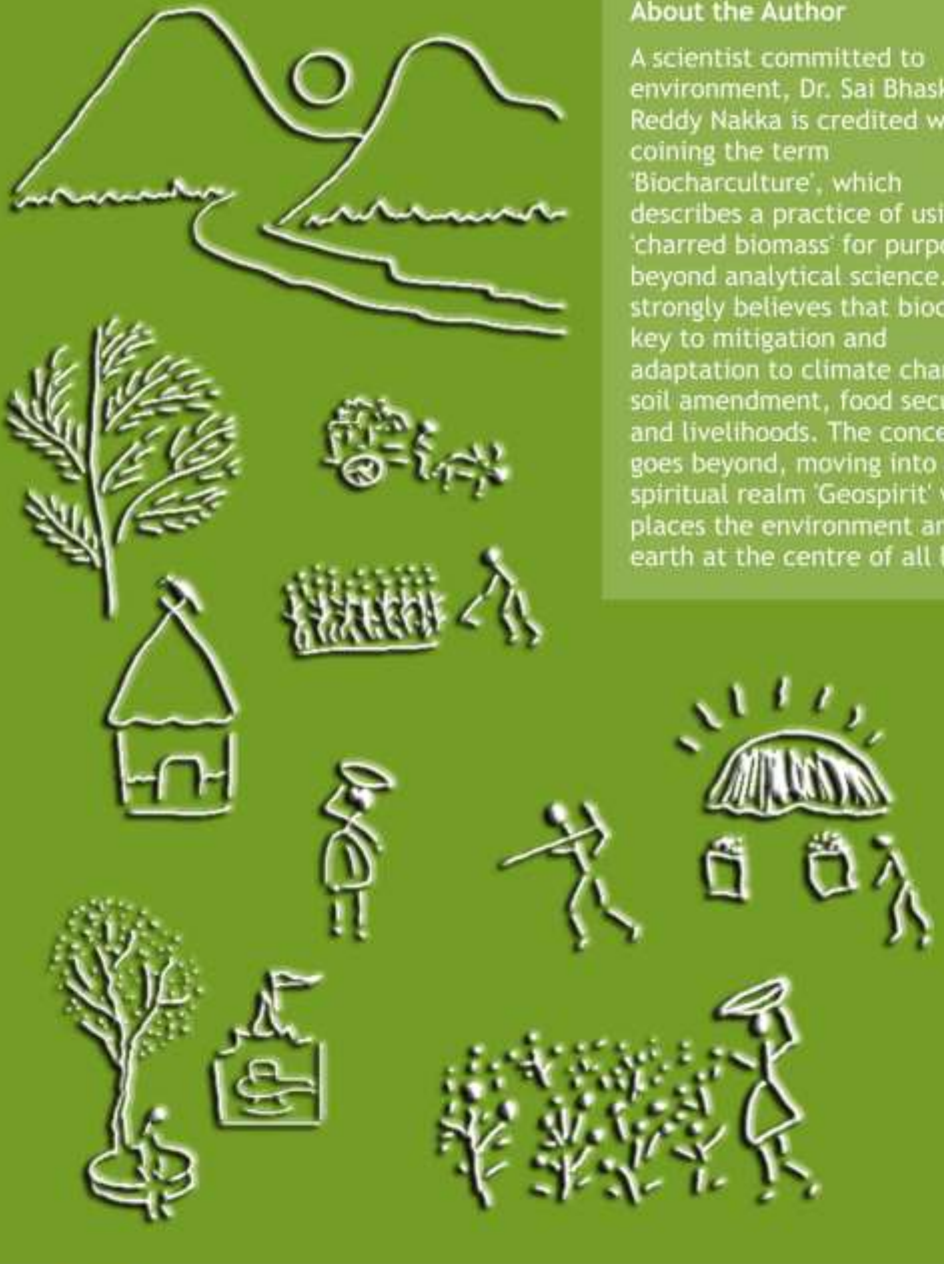
Good Stoves http://goodstove.com
BioEnergy Lists: Biochar Mailing Lists http://biochar.bioenergylists.org/
International Biochar Initiative http://www.biochar-international.org/

Supporting Organizations

MetaMeta, Netherlands - www.metameta.nl
3R Group, Netherlands - www.bebuffered.com
Geoecology Energy Organisation [GEO] – www.e-geo.org



About the Author

A scientist committed to environment, Dr. Sai Bhaskar Reddy Nakka is credited with coining the term 'Biocharculture', which describes a practice of using 'charred biomass' for purposes beyond analytical science. He strongly believes that biochar is key to mitigation and adaptation to climate change, soil amendment, food security and livelihoods. The concept goes beyond, moving into the spiritual realm 'Geospirit' which places the environment and the earth at the centre of all life.

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