Biochar Production: A Sustainable and Profitable Business Model for Farmers

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India is the second-largest agro-based economy wherein crop cultivation is taken all around the year, producing a large amount of agricultural waste, including the crop residue otherwise the stubbles. The prime means of disposing of the stubbles, in North India, is being the stubble burning that has popped out as a major issue of environment issue, severely affecting the air quality of the Delhi NCR, since 2015. This steers to serious health threats and ultimately global warming. The principal adverse effect of stubble burning on the environment is the emission of greenhouse gases (GHG's) and raised levels of particulate matter (PM) that engender global warming and loss of biodiversity of agricultural lands. Burning of crop residues releases increased quantity of air pollutants viz., CO_2, CO, NH_3, NOx, SOx, Non-methane hydrocarbon (NMHC), volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs) and particulate matter compounds (SVOCs) and particulate matter. Biochar can serve as a potential ingredient to remediate the problem caused by the stubble burning. There are many reports available presenting the scope of biochar in improving soil nutrient status, plant productivity and mitigation of greenhouse gases and are discussed in this section.

Biochar is defined as a carbon-rich material produced during pyrolysis process that is a thermochemical decomposition of biomass with a temperature about ≤700°C in the absence or limited supply of oxygen. The global biochar market reached a valuation of US$ 8 Million in 2020, which amounts to around 0.23% share of the overall charcoal market. Sales of biochar are slated to rise at a CAGR of 11% to top US$ 23 Million by 2031. Demand for pyrolysis technology in biochar is set to increase at a CAGR of 10% across the assessment period of 2021 to 2031. As per Fact.MR, a market research and competitive intelligence provider, the global biochar market was valued at US$ 8 Million in 2020. Biochar sales are primarily driven by its growing use as a charcoal alternative and widening applicability in electricity and power generation. Non-energy applications also remain a major booster to biochar sales. Carbon sequestration and water retention properties of biochar and driving demand for biochar in agriculture. Though the use of biochar in building materials, plastics recycling, and as a carbon black alternative is currently at its nascent stage, its industrial applications are likely to grow as government agencies continue to research in this area. Growing demand for biochar in electricity production, rising adoption of gasification biochar systems, and increasing sales of biochar in agriculture are driving the market growth. All of these factors are expected to drive the biochar products market at 11% CAGR over the 2021 to 2031 forecast period.

Problem

After the harvest of agricultural product, tons of agriculture waste are generated. Example - cotton stock, paddy straw, ground nut shells, etc. Farmers burn this waste product or they use this products as cattle feed. Burning of the agriculture waste causes tremendous pollution by releasing harmful greenhouse gases in atmosphere.

Reasons

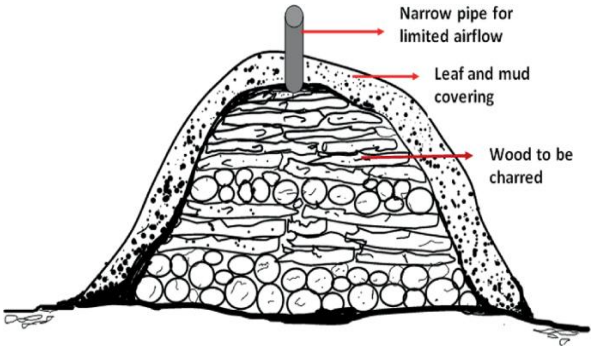
Absence of proper agricultural waste management technologies. If the technologies are present that are expensive and not feasible to use by individual farmers. No incentive to farmers to use agriculture waste management practices.

Solutions

The proper solution for this problem is, to utilize the agriculture waste generated for production of the biochar by continuous biochar reactor. The produced biochar is further used for application in the soil as a soil health improving agent or biochar can also be used as burning fuel for heat generation.

Biochar

Biochar is a carbon rich charcoal that is formed by the pyrolysis (thermal decomposition) of organic biomass or agricultural residues which is used as soil amendment. It is composed of carbon (C), hydrogen (H), oxygen (O), nitrogen (N), sulphur (S) and ash in different proportions. It is mainly used to improve soil nutrient content and to sequester carbon from the environment. It's highly porous structure makes it attractive option for soil amendment as it improves water holding capacity of the soil by increasing the total surface area of the soil. Due to large availability of biomass resources, India has great potential towards production of biochar. The properties of biochar can change extensively, depending on what the biochar is prepare from and how it is complete. Some biochar can have characteristics which make them an excellent amendment in one soil but not another.



Pyrolysis Technology

Biomass that is heated between temperatures of 300-600°C typically is referred as a slow pyrolysis product, as the process time can take many hours. The benefit of the slow pyrolysis process is that up to 40% of the biomass input can be converted to biochar. The fast pyrolysis process occurs at temperatures above 600°C and can be completed in minutes, this process produces higher ratios of oil and syngas and less biochar. Use of pyrolysis technology for biochar production will continue to grow, as it produces rich in carbon content and highly stable yield. Pyrolysis technology is widely used by several market players for high and stable yield production of biochar market. Various feedstocks and a large device (reactors) are utilized to make biochar through pyrolysis. Usually employed reactors contain: bench scale fixed bed, well swept fixed bed, fluidized bed and auger vertical tubular kinds.

A higher biochar yield was found with a slow pyrolysis process than with others. Based on the mode of operation, pyrolysis reactors can be classified as batch, semi-batch and continuous. The batch type pyrolysis plant doesn't need pre-treatment devices and the raw materials can be put into the reactor directly. In the batch-type biochar reactors, biomass materials are fed in different batches, and biochar is prepared by firing agro residues in air tight drum. Biochar yield in batch type process varies from 12.5 – 30%. In continuous type pyrolysis as the name indicted the reactor, the biochar produced in the continuous uninterrupted way in the continuous biochar reactor. It consists of the feed hopper, screw conveyor, heating mechanism etc. These types of reactors are suitable for uninterrupted commercial production of biochar. Biochar yield in continuous type varies from 25 – 40%.

In Heaping and charring method biomass is piled up to a height of about three to four feet and is covered with mud paste.

Vents are opened starting from the top and working downwards on drying of mud paste. The heap is set fire from one end and let to smoke for a considerable time period usually few days to week. In biochar kiln method bricks and clay are used in the construction. The biomass is added continuously as the fire continues. Air is allowed to enter from bottom as long as biomass is added continuously while burning. As the biomass reaches the level just below the secondary air vents, further addition of biomass is stopped and then the bottom vent is also closed. After some time, water is sprinkled to extinguish the fire and biochar is collected after some time. In drum method various forms of drum have been developed. Some have in horizontal and others are in vertical. Also, some require external heating, the other may need initial sparking for burning. There is hardly any control over the temperature and air supply. Also, the pyrolyzed biomass may not be uniform. The ash content in biochar is also high. Above developed technologies having minimal control over temperature, air supply and time parameters. Biochar is formed under oxygen stress conditions but there is no perfect control over temperature.

Table 1. Biochar production technologies, time required and biochar yield

Sl. No.	Type	Time	Char yield (%)
1.	Pit	Few days - week	12.50 – 30.00
2.	Heap	Few days - week	15.00 - 20.00
3.	Kiln, brick walled	1.00 – 5.00 h	12.50 - 33.00
4.	Kiln, steel walled	1.00 – 5.00 h	18.90 – 31.40
5.	Drum method	1.00 – 5.00 h	15.00 – 20.00
6.	Auger method	3 – 30 min	20.00 – 45.00

Auger or screw reactors operate continuously, which can be seen as an advantage to other reactor systems commonly used for slow pyrolysis, such as batch kilns, drum method and twin-retorts. Advantages of auger reactors include: flexible and reliable control of residence time by varying the screw speed and temperature by temperature controller.

Biochar Application

1. Biochar for soil health
2. Activated Carbone production from biochar
3. Biochar for water purification
4. Biochar as fuel
5. Biochar as a catalyst
6. Carbone Sequestration
7. Pharmaceutical industry
8. Construction sector uses
9. Sewage water treatment
10. Textile industry uses

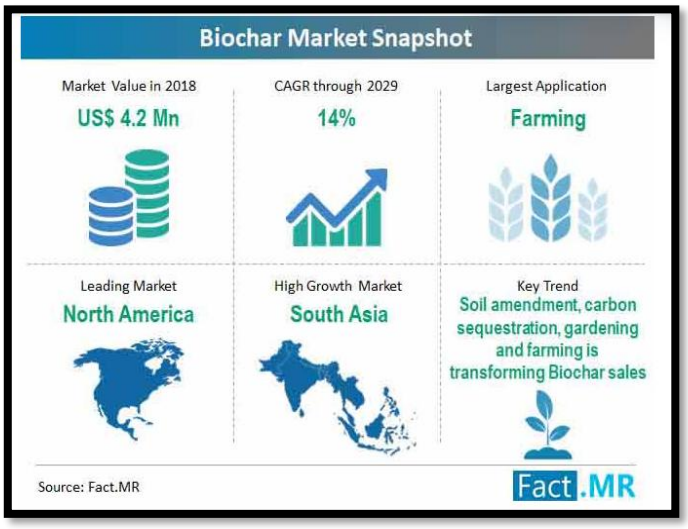
Biochar for soil health

Biochar has potential to sequester carbon in soils and simultaneously improve soil quality and plant growth. Agriculture is likely to be the largest biochar application over the coming years, and it is expected to maintain its dominance. Biochar increases water and fertilizer holding capacity of the soil, providing important nutrients to crops and

promoting plant growth. In a lot of pot and field studies, biochar has been shown to get better crop yields when compared to suitable controls where biochar was not applied. The use of Biochar has been gradually increasing in developing countries because it can improve the physical and chemical properties of soil and increases soil fertility and productivity to increase crop strength and growth with fewer emissions. The special ability of Biochar is to retain nutrients and water in the surface soil horizons. In developing countries, governments are encouraging people to use biochar for farming as it can minimize greenhouse gases like nitrous oxide and methane emissions and maximize the crop production. It boosts soil fertility and gives crops the nutrients they require. Yield improvements with biochar have been qualified to the following effects: 1) Increase in pH, the pH of biochar is often high (e.g. >9). This is beneficial in soil where the pH is lesser than optimal for the intended use, but not if the pH is higher than best; 2) Immediate or direct addition of nutrients. Ash in biochar contributes some nutrients to soil, but this is a short-term effect; 3) Retention of nutrients substances. With the passing of time, biochar surfaces advance an ability to retain nutrients in soil. This is a lengthy - period advantage of biochar and sets it apart from other forms of biological materials in soil, which also help retain nutrients but decompose relatively quickly; 4) Potential improvement of soil physical properties. Biochar has an extremely low density & highly porous; 5) Biochar may provide suitable situations for advantageous microbes soil, for example N-fixing Rhizobia and Mycorrhizal fungi.

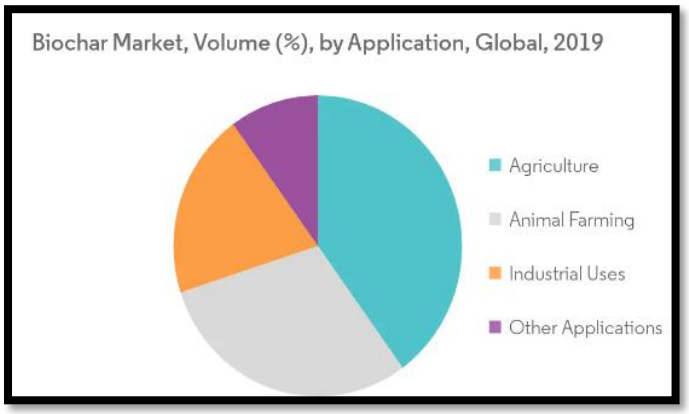
Biochar application in soil acts as a conditioner and plays a much more important role in improving crop growth than as a fertilizer itself. Biochar can be used as a soil amendment to improve soil quality, to increase soil pH and CEC, improve water quality, increase soil moisture retention, reduce emission of greenhouse gases from soil, leaching of nutrients, soil acidity, irrigation and fertilizer requirements and also to reclaim degraded and spoiled land. The application of biochar to soil has been shown to improve crop yields which could be due to direct or indirect effect. The direct effect explained by fact that biochar being concentrated during pyrolysis contains higher amount of nutrients than the biomass from which they are prepared. The indirect effect is due to improvement in soil physical, chemical and biological properties due to biochar application. Organic manures improve soil properties and nutrients use efficiency but in tropical condition they mineralize quickly resulting lesser benefits, while a fraction of biochar remains in soil in a very stable form for a long time. Biochar application boost up the available water content of the soil up to 97 percent and saturated water contents 56 percent. Biochar amended soil retained 15 % more moisture contents as compared controlled treatment. Biochar application increased the water retention capacity of the soil because it increases soil porosity and also due to adsorptive nature of biochar.

Biochar Market



The growing need for quality food and with the most population getting attracted to various organic crop foods India, the demand for biochar is augmenting in various farming processes. The

demand for growing high-quality crops for organic food and continuous development in farming are the key driving factors for the market growth. According to a new report by EMR titled, 'Global Biochar Market Report and Forecast 2021-2026, the global biochar market size was valued at USD 1.67 billion in 2020. The market is further expected to reach USD 3.24 billion by 2026, with a CAGR of 11.8% during 2021-2027. Biochar is a developing industry that is expected to play a significant role in increasing crop production and productivity in the agricultural sector. International biochar experts Albert Bates and Kathleen Draper estimate that biochar as a soil amendment will only ultimately represent 5% of the global market for biochar in the future.



Major Factors Driving the Growth of Biochar Market

Biochar can increase soil fertility, water holding capacity and crop productivity. The increase in soil fertility leads to increased crop production. This feature is expected to drive the biochar market. A large number of market players are improving their R&D capabilities to explore the potential application of biochar in the generation of electricity, and nutrition retention of soil. This in turn is expected to provide a lucrative biochar market growth opportunity.

Market Strategy and Marketing Plan

By producing biochar from this machine farmers can sell this biochar to other farmers in term they can earn money, also can be sold to bio-fertilizers manufactures as raw materials. Farmers can sell their agriculture waste to biochar production unit in this way farmers can earn money. Industrialists can also setup commercial biochar production unit and that way they can earn money. Also blended biochar product sell to market.

Marketing

Products and Price

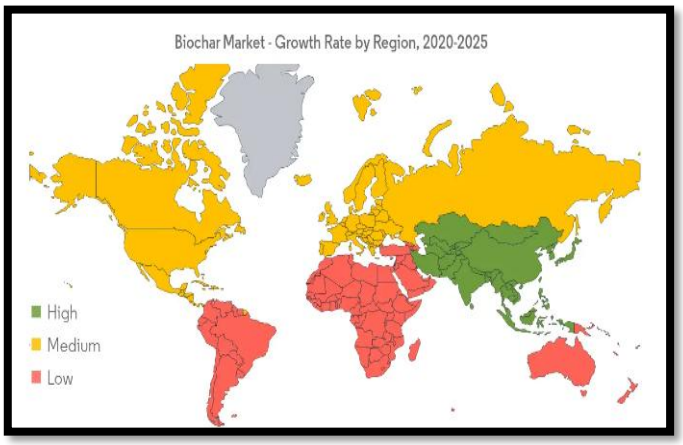
100% pure biochar and mixed with other fertilizers by the consumer and biochar compost/fertilizer mixes, which are formulated to meet specific soil amendment needs.

Distribution

Distribution of biochar is a large expense for any biochar business. Both models face similar concerns when it comes to the packaging and shipping of biochar.

Promotion

To large-small farmers, home gardeners,



managers of city parks, golf courses and university campuses and wineries etc.

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