

PCW Biochar System: In-Situ Agricultural Pyrolysis and Multi-Strata Agroforestry as a Strategy for Massive Carbon Sequestration and Soil Restoration

Abstract

This article presents the PCW Biochar System, an approach combining in-situ agricultural pyrolysis and multi-strata agroforestry to increase carbon sequestration while restoring soil fertility.

The system is based on two main stages. The first stage consists of producing biochar directly on the field from local biomass using flame-curtain pyrolysis carried out in a biomass windrow. This method converts part of the biomass into stable carbon incorporated into the soil.

The second stage involves the development of a high-biomass multi-strata agroforestry system integrating fast-growing trees, giant grasses, nitrogen-fixing plants, and permanent ground cover.

Under the studied temperate climate conditions, the system could produce approximately 150 to 180 tonnes of biomass per hectare per year and enable a net storage estimated between 80 and 100 tonnes of CO₂ per hectare per year.

At large scale, the implementation of this system across several hundred million hectares could represent a significant potential for atmospheric carbon reduction while improving agricultural productivity and soil resilience.

The article also highlights that multi-strata agroforestry systems in tropical climates could reach even higher biomass production levels, potentially increasing both biochar yield and carbon sequestration.

Introduction

Climate change represents one of the major challenges of the twenty-first century. Greenhouse gas emissions resulting from human activities have led to a rapid increase in atmospheric carbon dioxide concentrations.

At the same time, many agricultural soils have lost a significant portion of their organic matter, reducing their capacity to store carbon and maintain fertility.

In response to these challenges, several strategies have been proposed to increase carbon sequestration in soils. Among them, biochar production and agroforestry systems appear to be particularly promising solutions.

The PCW Biochar System proposes to combine these two approaches within an integrated agricultural system capable of producing large quantities of biomass while transforming part of this biomass into stable carbon stored in the soil.

General Principle of the PCW Biochar System

The PCW Biochar System is based on a biomass management cycle integrating plant production, partial thermal transformation, and carbon stabilization in soils.

The system includes two main phases. The first phase consists of producing biochar directly on the field from agricultural biomass using in-situ pyrolysis. The second phase involves the establishment of a multi-strata agroforestry system designed to maximize biomass production and atmospheric carbon capture.

Initial Biomass Production

The first year of the system is dedicated to producing biomass intended for biochar production. The species used are selected for their rapid growth and high biomass productivity.

- *Paulownia tomentosa*
- *Populus nigra*
- *Robinia pseudoacacia*
- *Alnus glutinosa*
- *Miscanthus x giganteus*
- *Cannabis sativa*

Fast-growing trees produce woody biomass rapidly and contribute to structuring the future ecosystem. Some species, particularly *Robinia pseudoacacia* and *Alnus glutinosa*, also have the capacity to fix atmospheric nitrogen through bacterial symbiosis.

The biomass produced during this phase is then used for biochar production.

Biochar Production through In-Situ Agricultural Pyrolysis

Biochar production is carried out in a biomass windrow placed on the soil surface. The geometry of the windrow is optimized to control combustion and favor pyrolysis.

- Base width: approximately 5 meters
- Height: approximately 1.5 meters
- Length: variable depending on the amount of biomass

The biomass is arranged longitudinally in order to facilitate the progression of the pyrolysis front. During controlled combustion, the pyrolysis gases produced by the thermal decomposition of biomass burn in the upper layer of the windrow, forming a flame curtain that limits oxygen supply to the lower layers.

This process transforms part of the biomass into biochar rich in stable carbon.

Initial Biochar Application

After pyrolysis, the biochar is distributed across the field.

Typical application rate: 20 to 30 tonnes of biochar per hectare.

Biochar generally contains 70 to 85 percent stable carbon. This corresponds to an immediate storage of 60 to 90 tonnes of CO₂ per hectare.

- Improved water retention
- Increased cation exchange capacity
- Enhanced microbial activity
- Development of mycorrhizal networks

Economic Cost Comparison

Compared with conventional biochar production technologies, the PCW Biochar System significantly reduces operational costs by producing biochar directly on agricultural land using in-situ flame-curtain pyrolysis, eliminating the need for centralized infrastructure and long-distance biomass transport.

Industrial pyrolysis plants typically require investments of several million euros and produce biochar at costs ranging from 500 to 1200 euros per tonne. Small metal kilns or batch reactors generally produce biochar at 200 to 600 euros per tonne, and Kon-Tiki systems at approximately 100 to 300 euros per tonne.

In contrast, the PCW Biochar System relies primarily on locally produced biomass and standard agricultural equipment, allowing estimated production costs of roughly 30 to 120 euros per tonne of biochar depending on labor and mechanization levels.

When converted to carbon removal costs, this corresponds to approximately 7 to 40 euros per tonne of CO₂ sequestered, which is substantially lower than most technological carbon removal solutions such as Direct Air Capture (500 to 1000 euros per tonne CO₂) or BECCS (100 to 200 euros per tonne CO₂).

Multi-Strata Agroforestry System

After biochar introduction, the field is organized according to a multi-strata agroforestry system. This system combines several vegetation layers in order to optimize solar capture and biomass production.

- Main canopy of fast-growing trees
- Secondary trees
- Shrubs
- Vines
- Giant biomass plants
- Nitrogen-fixing root meadows
- Permanent ground cover

Annual Biomass Production

In a temperate climate, annual biomass production may reach 150 to 180 tonnes of dry biomass per hectare per year.

Plant biomass contains approximately 45 percent carbon. Annual carbon capture may therefore reach 67 to 80 tonnes of carbon per hectare per year.

In carbon dioxide equivalent, this corresponds to approximately 245 to 295 tonnes of CO₂ captured per hectare per year.

Carbon Storage

In agroforestry systems, approximately 30 to 40 percent of captured carbon may remain stored within the ecosystem. Annual storage may therefore reach 75 to 100 tonnes of CO₂ per hectare per year.

- Biochar
- Soil organic matter
- Deep roots
- Permanent woody biomass

Global Deployment Potential

If this system were deployed across approximately 300 million hectares, the annual carbon sequestration potential could reach 24 to 30 gigatonnes of CO₂ per year.

Potential under Tropical Climates

Multi-strata agroforestry systems in tropical climates can produce 250 to 400 tonnes of biomass per hectare per year. Under such conditions, biochar production and carbon sequestration could be significantly higher than those observed in temperate climates.

Limitations and Uncertainties

The estimates presented rely on several simplified assumptions. Actual system performance may vary depending on climatic conditions, initial soil fertility, water availability, and agricultural management practices. Experimental studies will be necessary to validate system performance in different contexts.

Research Perspectives

- Experimental evaluation of soil carbon storage
- Optimization of agricultural pyrolysis techniques
- Selection of high-biomass plant species
- Assessment of tropical agroforestry systems potential

Conclusion

The PCW Biochar System combines in-situ agricultural pyrolysis with multi-strata agroforestry in order to create a system capable of restoring soils while durably storing carbon. Under optimized conditions, the system could enable net carbon storage estimated at 80 to 100 tonnes of CO₂ per hectare per year.

At large scale, such systems could contribute significantly to the reduction of atmospheric carbon while improving soil fertility and the resilience of agricultural systems.

Reference

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