© July 2025| IJIRT | Volume 12 Issue 2 | ISSN: 2349-6002

Pine Needle (Pinus Roxburghii) Biochar Production Using Solar Dryer System

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Abstract: **This paper presents a sustainable approach for converting pine needle biomass into biochar using a solar-powered drying system followed by pyrolysis. Pine needles, which are a major cause of forest fires in Uttarakhand, can be transformed into high-quality biochar, which has multiple applications in soil improvement, carbon sequestration, and renewable fuel. This system includes a flat-plate solar dryer for pre-treatment, reducing moisture content to enhance pyrolysis efficiency. The results indicate that the solar-dried pine needles yield 22–25% biochar with good carbon content and porosity. The approach provides a clean, low-cost, and scalable solution to mitigate environmental hazards and support rural livelihoods.**

Keywords- Biochar; Solar Dryer; Pine Needles; Forest Waste; Renewable Energy; Pyrolysis

1.INTRODUCTION

Pine trees are abundant in Uttarakhand's forests and shed large quantities of dry needles every year. These dry pine needles accumulate in forest floors, increasing the risk of wildfires and ecological degradation. However, this biomass contains valuable lignocellulosic content and can be utilized to produce biochar—a carbon-rich material obtained through pyrolysis. Biochar improves soil fertility and water retention and acts as a carbon sink.

This paper proposes a solar-assisted method for biochar production, combining a solar dryer for moisture removal and a low-tech pyrolysis system. This dual-phase process enhances yield, lowers emissions, and offers a circular solution for forest waste management.

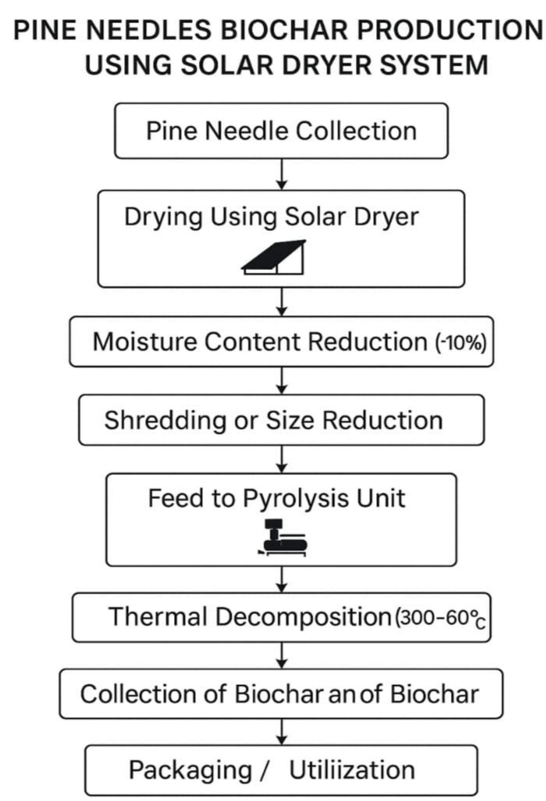
2.SYSTEM DESCRIPTION

The proposed system integrates solar energy for drying and a pyrolysis kiln for biochar conversion. Solar dryers reduce the moisture content of pine needles from ~40% to ~12%, enabling efficient thermal decomposition. The system components include:

- Solar Dryer (flat-plate type with transparent sheet cover)
- Portable Pyrolysis Kiln (retort drum design)
- Temperature and moisture sensors
- Basic testing equipment for biochar quality assessment

The process ensures zero fuel cost for drying and minimum emissions due to controlled pyrolysis.

Flow Chart



3.DESIGN AND IMPLEMENTATION

The flat-plate solar dryer is constructed using an aluminum base, a polycarbonate sheet as cover, and side vents for natural convection. Pine needles are laid evenly inside the chamber. Drying occurs over 4–6 hours under sunny conditions.

The pyrolysis unit is a modified steel drum, insulated with clay and bricks, and heated using residual pine biomass. Pine needles are carbonized at 400–500°C for 90–120 minutes, resulting in stable biochar.

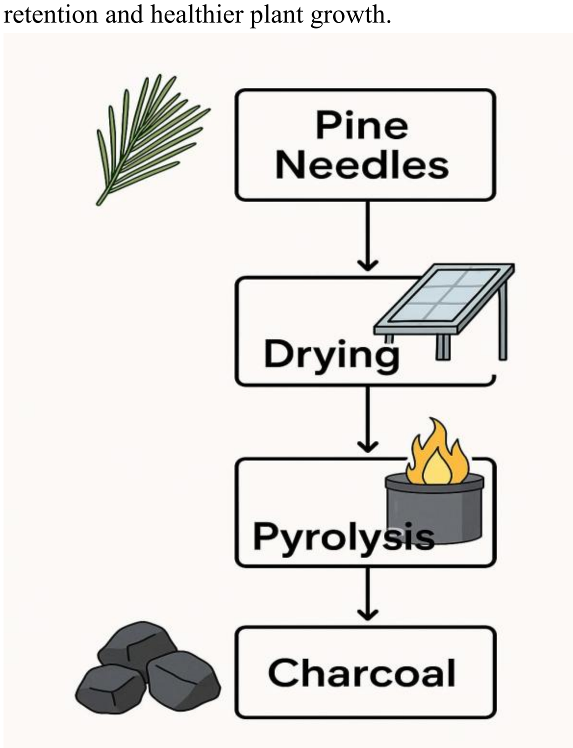
A small community-level unit was implemented in Uttarakhand and Himalayan Region, and trials were conducted over 5 days.

4.RESULTS AND DATA ANALYSIS

The drying efficiency of the solar dryer brought moisture content from 40% to 12%. Biochar yield was recorded at ~22–25% by dry weight. Tests revealed the following average characteristics:

- pH: 8.5
- Carbon Content: ~60%
- BET Surface Area: ~275 m^2/g
- Calorific Value: ~21 MJ/kg

Field feedback from farmers using biochar in vegetable plots showed improved soil moisture retention and healthier plant growth.



5. CONCLUSION

This work demonstrates a viable and eco-friendly solution to the problem of pine needle accumulation and forest fires. By converting waste into biochar using solar energy, the system promotes environmental protection, rural employment, and agricultural productivity. The system is cost-effective and can be scaled to other regions with similar forest profiles.

6. ACKNOWLEDGMENT

The author sincerely thanks the local forest department officials and villagers of Pauri Garhwal for their support during the trial implementation and data collection phase.

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