RESADE

Improving Agricultural Resilience to Salinity Through the Development and Promotion of Pro-Poor Technologies

Producing Biochar

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Summary

The RESADE project Improving Agricultural Resilience to Salinity through the Development and Promotion of Pro-Poor Technologies and Management Strategies in Selected Countries of Sub-Saharan Africa operates in seven countries. The RESADE project provides customized agronomic strategies tailored to saline environments. These strategies include innovative crop management methods and efficient irrigation techniques, such as various irrigation systems and improved soil management practices. Notably, the use of soil amendments such as biochar helps decrease further salinization while also increasing crop productivity.

Biochar is a carbon-rich material produced through the pyrolysis of organic biomass in an oxygen-free environment. This training handout offers an overview of the principles, environmental benefits, and practical steps involved in biochar production, emphasizing its importance in enhancing agricultural resilience, particularly in saline and degraded soils. It outlines the necessary materials, unit design, biomass selection, and the pyrolysis process, while also addressing environmental considerations and safety protocols. This document serves as a practical guide for farmers, technicians, and development practitioners seeking to implement sustainable soil management practices, thereby contributing to climate change mitigation through carbon sequestration and enhanced soil health.

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Overview

Biochar is a carbon-rich and durable material produced through pyrolysis, a process that involves heating organic biomass such as agricultural residues (e.g., straw and maize stalks, wood chips from forestry operations, or other types of organic waste) in an environment with limited oxygen. This thermochemical transformation converts biomass into a porous substance that can greatly enhance soil quality when added. This innovative method is increasingly gaining popularity in sustainable agriculture for various reasons. Biochar offers several key benefits for farming, such as enhanced soil fertility and structure, improved water retention, and increased nutrient availability. It supports beneficial microbial activity, which is vital for maintaining long-term soil health, and helps decrease greenhouse gas emissions while promoting carbon sequestration. Consequently, biochar is being more widely adopted in farming practices worldwide, particularly in regions facing concerns such as soil salinity, low organic matter, and water scarcity, thereby contributing to a more sustainable agricultural future and enhancing food security.

Positive Environmental Impacts of Biochar

Biochar offers numerous environmental benefits, including effective carbon sequestration, which helps mitigate climate change by locking carbon in the soil for hundreds of years. It improves soil health by enhancing structure, nutrient retention, and water-holding capacity, while also diminishing the leaching of fertilizer. Additionally, biochar aids in waste management by converting agricultural and forestry waste into valuable soil amendments, thereby decreasing air pollution caused by open burning. It can also reduce emissions of potent greenhouse gases, such as nitrous oxide and methane, enhance microbial activity for improved nutrient cycling, and help mitigate soil salinity and pollution by immobilizing heavy metals and organic contaminants.

Carbon Sequestration

Biochar represents a stable carbon compound that has the potential to persist in soil for hundreds to thousands of years. Its use is significant in the reduction of atmospheric carbon dioxide levels, thereby contributing to climate change mitigation efforts.

Improved Soil Health

Biochar significantly improves soil structure, increases porosity, and enhances water-holding capacity. It also promotes nutrient retention and minimizes the leaching of fertilizer into groundwater.

Waste Management

Biochar is produced by transforming agricultural and forestry waste, such as crop residues, wood chips, and date palm fronds, into a valuable soil amendment. This process effectively mitigates the open burning of biomass, leading to a significant decrease in air pollution and particulate emissions.

Reduced Greenhouse Gas Emissions

Biochar-amended soils have the potential to reduce emissions of nitrous oxide (N_2O) and methane (CH_4), both of which are significant greenhouse gases.

Enhanced Microbial Activity

Biochar contributes to the creation of an environment conducive to beneficial soil microorganisms, thereby enhancing nutrient cycling and promoting overall plant health.

Salinity and Pollution Mitigation

Biochar serves to mitigate the effects of salinity in soils and effectively immobilizes heavy metals and organic pollutants, thereby decreasing their bioavailability in the environment.

Environmental Considerations

Biochar production plays a significant role in promoting environmental sustainability, and its effectiveness is heavily influenced by the selection and management of feedstock, primarily biomass waste materials. These biomass sources, often termed biochar precursors in the scientific literature, consist of organic materials derived from agricultural, industrial, or municipal waste that can be converted into biochar. To mitigate ecological risks, such as deforestation and biodiversity loss, it is essential to select suitable biomass sources responsibly. Ensuring sustainable collection practices is vital to prevent environmental degradation and resource depletion. By prioritizing the sustainable management of biomass, we can maximize the benefits of biochar while protecting ecosystems.

Biomass Source Sustainability

Make sure that the organic materials for biochar are gathered through environmentally responsible methods. Avoid obtaining biomass from activities such as unsustainable logging, land clearing, or habitat destruction.

Production Emissions

In the production of biochar, it is critical to recognize that inadequate management of the pyrolysis process can result in the emission of harmful gases. Therefore, the implementation of adequate and efficient systems is essential to mitigate these emissions and enhance overall safety and sustainability.

Soil and Crop Specificity

The effects of biochar are influenced by soil type, crop selection, and climatic conditions. Therefore, conducting field trials is essential prior to implementing widespread applications.

Selecting Sustainable Feedstock

Biochar can be derived from a diverse range of biomass waste materials:

- Agricultural residues – crop stalks, husks, and shells.
- Forestry waste – sawdust, bark, and thinning residues.
- Municipal organic waste – yard trimmings and food scraps.
- Animal manure.

These materials are often underused or disposed of improperly, frequently being burned or left to decompose, which results in the release of greenhouse gases such as carbon dioxide and methane. Converting them into biochar presents a valuable opportunity to sequester carbon while improving soil health.

Biochar production at the farm level

1. Biochar unit: producing biochar equipment for farmers

a. Materials needed

The biochar unit comprises three essential components that work synergistically. The materials required for hands-on training related to its fabrication are straightforward and uncomplicated (Table 1).

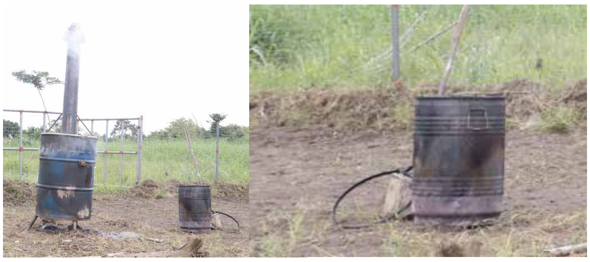
- **Large drum:** A standard drum, commonly available in the local market. This drum will function as the outer combustion chamber:
    - **Capacity:** 55 US gallons (208 liters).
    - **Height:** Typically ranges from 84 to 89 cm, with slight variations depending on design (open-head or tight-head).
    - **Diameter:** Generally, 56 to 61 cm.

- **Small drum with cover:** The diameter of this drum should be 50% to 60% of that of the large drum. It is designed to hold the biomass securely.

- **Metal sheet for chimney:** Using longer chimneys enhances the production of cleaner emissions. The chimney should be constructed from metal sheets to facilitate improved airflow and minimize smoke output.

Photo 1. Materials needed to set up the biochar unit.

Table 1. Specifications of the materials that can be used to set up the biochar unit.

Material	Unit	Photo	Note
Big drum (standard, commonly available in the local market)	-		The size can be 208 liters. Dimensions of 56 to 61 cm in diameter and 84 to 89 cm in height. The size depends on the locally available material.
Small drum with cover	-		A small drum with a cover should be smaller than the big drum (50% to 60% of the diameter).
A metal sheet to make the chimney	-		The longer the chimney, the cleaner the smoke.

All of the required materials for fabricating the biochar unit can be sourced from local hardware stores or metal workshops. When purchasing, ensure that each item matches the specifications outlined earlier, particularly the size and type of drums and metal sheets. It is essential to prioritize safety and cleanliness: avoid using containers that have previously held chemicals, oils, or any hazardous substances. Reused drums must be thoroughly cleaned and confirmed safe for high-temperature use. Choosing the right materials not only ensures the effectiveness of the biochar unit but also protects the health of users and the environment.

Photo 2. Example of obtaining materials needed for biochar units from local shops in one of the RESADE project countries.

b. Design of the biochar unit

The following illustration shows a simple yet effective design for biochar production units. This design includes key components, such as a standard drum (84 to 89 cm in height by 56 to 61 cm in diameter) acting as the outer combustion chamber, and a smaller drum (50% to 60% smaller) with a cover serving as the reactor chamber in which pyrolysis takes place. A chimney is included to manage emissions efficiently. The reactor chamber will be constructed from locally available metals that can withstand high temperatures, thus ensuring good heat retention. The overall design emphasizes ease of use and functionality, enabling the production of high-quality biochar while minimizing environmental impact

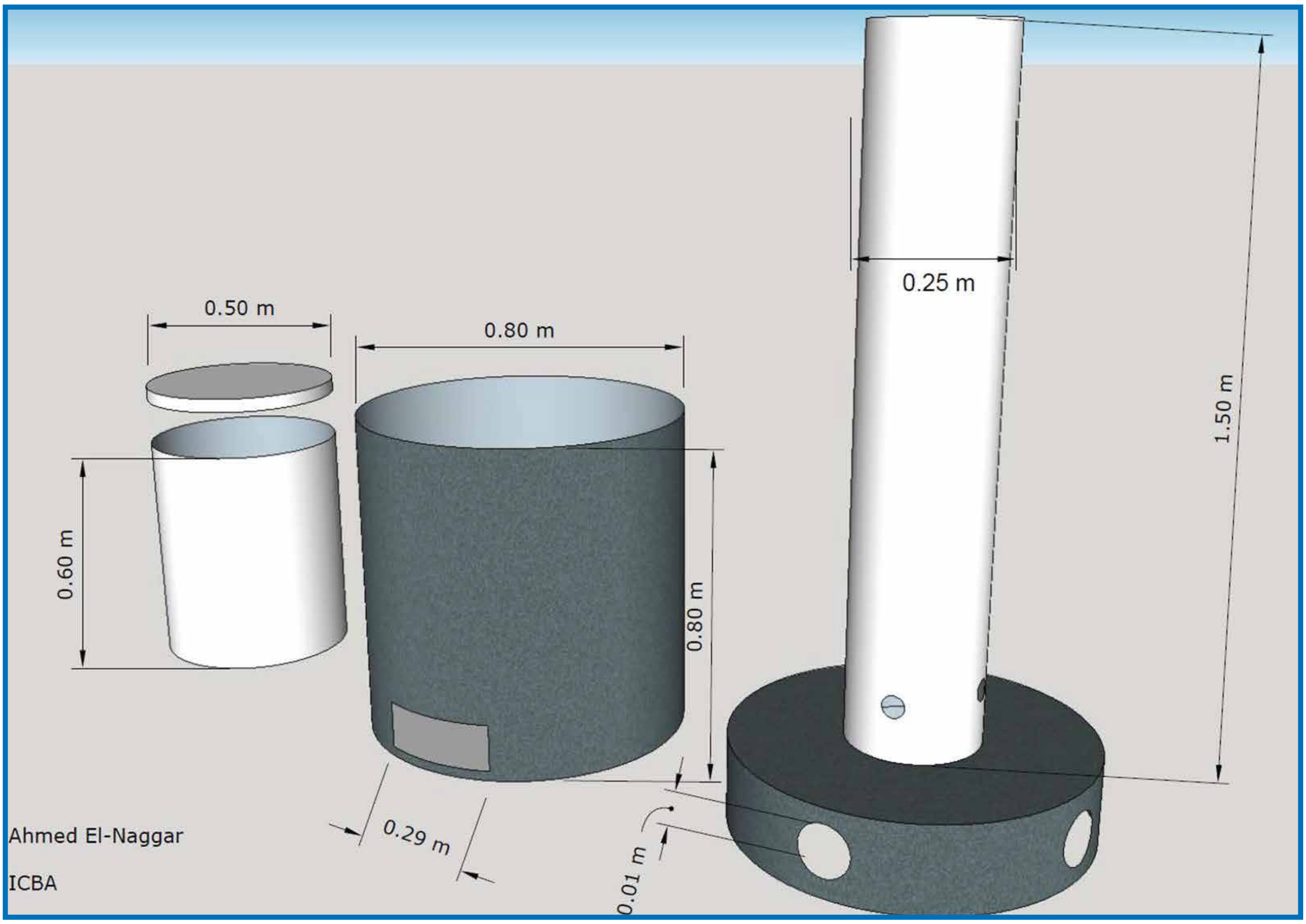


Figure 1. Illustration of the biochar unit design.

2. Biochar production

a. Biomass selection

Choosing the right biomass is essential for producing high-quality biochar. The best materials are dry, organic, and sustainably sourced options that are readily available. Common choices are crop residues, such as maize stalks and rice husks, as well as coconut shells, pruned branches, and wood materials such as sawdust or wood chips.

These materials are effective because they contain high amounts of carbon, which helps produce biochar with good porosity and nutrient retention. Using agricultural waste promotes sustainable farming practices and helps mitigate open burning, resulting in cleaner air and improved resource management.

Use dry organic materials such as

- Crop residues (maize stalks, rice husks)
- Coconut shells
- Pruned branches
- Sawdust or wood chips

b. Pyrolysis process

Pyrolysis constitutes the fundamental process in the production of biochar, wherein organic biomass undergoes thermal decomposition in an oxygen-free environment that converts raw biomass into a stable, carbon-rich form known as biochar while concurrently minimizing CO2 emissions. The operation requires a simple but meticulous setup and continuous monitoring to ensure both safety and efficiency. The following outlines the essential steps involved in this process:

- Fill the inner drum with dry biomass.
- Place it inside the outer drum.
- Ignite the outer drum to begin heating.
- Biomass undergoes pyrolysis (excessive heating without igniting/burning in the inner drum).
- Monitor temperature and smoke; longer chimneys help decrease emissions.
- After 6–12 hours, allow the unit to cool.

c. Cooling and collection

- Let the unit cool completely to avoid combustion of biochar.
- Carefully remove the inner drum and collect the biochar.
- Crush and sieve if needed for uniform particle size.

3. Safety tips

- Always wear protective gloves and eyewear during fabrication and operation.
- Ensure proper ventilation when operating the unit.
- Keep a fire extinguisher nearby during pyrolysis.
- Allow the unit to cool completely before handling biochar.

4. Application in soil

Application Rates for Soil Amendments:

When applying soil amendments, it's essential to select the appropriate rate based on the soil conditions:

- **Low Rate (2–5 tons/ha):** This range is suitable for initial trials and normal farming conditions or when mixing with compost or manure. It allows a cautious approach while evaluating your soil's response.
- **Moderate Rate (5–10 tons/ha):** Suitable for soils that are moderately degraded or facing saline conditions. This application can help improve soil health and fertility.
- **High Rate (10–20 tons/ha):** This increased application rate targets severely degraded soils or those with high salinity levels, where significant remediation is required.

Before launching large-scale projects, it's important to run small-scale field trials. This step helps you assess how your local soil responds to the amendments, leading to better results.

Application Methods

- **Broadcast and Incorporate:** This method involves spreading the material evenly over the soil surface and mixing it into the top 10-15 cm of soil to ensure uniform distribution.

- **Banding or furrow application:** This method involves placing the material directly into the planting rows to deliver nutrients selectively to crops.
- **Spot Application:** For specific planting scenarios, such as trees or shrubs, this method involves using the material directly in the planting holes to provide concentrated nutrition.
- **Combined with compost or manure:** Mixing the material with compost or manure can improve nutrient synergy and increase microbial activity in the soil, supporting healthy plant growth.

Application Methods

It is recommended to apply the material before planting or during the land preparation phase to optimize soil conditions. For perennial crops, the best timing for application is during their dormant seasons or in the early growth stages to support robust development.

5. Troubleshooting Guide

To enhance the practical value and applicability of Biochar, the following recommendations aim to address key gaps identified in biomass selection and the pyrolysis process.

Issue	Possible Cause	Solution
Excessive smoke	Wet biomass or short chimney	Use dry feedstock; extend the chimney
Incomplete pyrolysis	Low temperature or short duration	Increase heat; extend time
Fire inside the inner drum	Oxygen leakage	Seal the drum properly
Biochar too powdery	Overheating	Reduce temperature
Uneven biochar quality	Mixed biomass types	Use uniform feedstock

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INTERNATIONAL CENTER FOR BIOSALINE AGRICULTURE

Established in 1999 by the Government of the United Arab Emirates and the Islamic Development Bank, ICBA is a unique international not-for-profit applied research-for-development center. The center's approach integrates strategic alliances, technical expertise, and knowledge empowerment to co-create innovative solutions for sustainable livelihoods and food security in saline and arid environments. The center's research is at the nexus of soil, water, crops, and climate to prevent, manage and recover from salinity in agricultural lands. Through this holistic and integrated approach, ICBA strives to make a lasting positive impact on the lives and livelihoods of farming communities, ensuring their resilience and contributing to a more sustainable future for all.