Quantifying the influence of Eucalyptus bark and corncob biochars on the physical properties of an oxisol under maize cultivation

Boris Merlain DJOUSSE K.¹,²,a, Suzanne E. ALLAIRE¹,b, Alison D. MUNSON¹,a

¹ Université de Dschang
² Centre d’étude de la forêt

5th North American Biochar Symposium
August 22-25, 2016, Corvallis OR
The Congo Basin Forest

https://www.google.ca/maps/@25.6480575,3.379742,3z
Setting the scene: tropical forest / tropical soil

Farm practices that maintain soil fertility help avoid the cultivation of new lands (forested and natural).
Soil conservation for sustainable agriculture: Biochar?

Potential to improve soil fertility, sequester carbon in addition to other potential environmental services (Lehmann et al., 2006; Laird, 2008; Sohi et al., 2010).

**Properties**: Raw materials, pyrolysis temperature and age (Schmidt and Noack, 2000; Lehmann et al., 2011).

**Chemical properties**: Recalcitrant carbon, labile carbon and ash, low initial CEC, hydrophobic, high pH and high C/N.
Biochar: Physical properties

- High surface area
- High porosity (nano, micro, macro)
- Low bulk density

(Atkinson et al., 2010; Major et al., 2010)

- Bulk density ($\rho_a$)
- Total porosity ($\Theta$)
- Saturated hydraulic conductivity ($K_s$)
- Water content at saturation ($\Theta_s$)
- Residual water content ($\Theta_r$)
- Available water content (AWC)
Inconsistency in the effects of biochar on soil physical properties

- Unclear effects, sometimes contradictory (Hardie et al., 2013; Barnes et al., 2014; Jeffery et al., 2015; Ojeda et al., 2015; Omondi et al., 2016)

- Mainly influenced by biochar properties, soil type and cropping system

- Few studies conducted on the furrow-ridges system widely used in the Congo Basin Forest
Objective

To evaluate the effects of two types of biochar applied, at a rate of 15 t ha\(^{-1}\) on the physical properties of an oxisol (clay loam) and maize yield.

- Bulk density \((\rho_a)\)
- Total porosity \((\Theta)\)
- Saturated hydraulic conductivity \((K_s)\)
- Water content at saturation \((\Theta_s)\)
- Residual water content \((\Theta_r)\)
- Available water content \((AWC)\)
- Yield
### Experimental Design

<table>
<thead>
<tr>
<th>BLOCK 3</th>
<th>FP</th>
<th>T2</th>
<th>T3</th>
<th>T5</th>
<th>T1</th>
<th>T4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FR</td>
<td>T3</td>
<td>T4</td>
<td>T1</td>
<td>T2</td>
<td>T5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BLOCK 2</th>
<th>FR</th>
<th>T4</th>
<th>T1</th>
<th>T5</th>
<th>T3</th>
<th>T2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FP</td>
<td>T3</td>
<td>T5</td>
<td>T2</td>
<td>T1</td>
<td>T4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>BLOCK 1</th>
<th>FP</th>
<th>T4</th>
<th>T2</th>
<th>T5</th>
<th>T1</th>
<th>T3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FR</td>
<td>T2</td>
<td>T5</td>
<td>T4</td>
<td>T3</td>
<td>T1</td>
</tr>
</tbody>
</table>

**T1 = S**

**T2 = CCB**

**T3 = EB**

**T4 = CCB+S**

**T5 = EB+S**

N.B: Mineral fertilization (200kg/ha of NPK and 10 Kg/ha of N) applied on all plots

**FP = Flat plots**

**FR = Furrow-ridges plots**

**CCB = Corncob biochar**

**EB = Eucalyptus bark biochar**

**S = Straw**
Table 1. Summary of methods of analyses

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Methods / Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk density</td>
<td>$\rho_a$ Astm:D7263 (Core method)</td>
</tr>
<tr>
<td>Total porosity</td>
<td>$\Theta$ Calculations ($1-(\rho_a/\rho_s)$)</td>
</tr>
<tr>
<td>Saturated hydraulic conductivity</td>
<td>$K_s$ Constant head permeameter</td>
</tr>
<tr>
<td>Saturated water content</td>
<td>$\theta_s$ Tension table + pressure plate</td>
</tr>
<tr>
<td>Residual water content</td>
<td>$\theta_r$ Modelling using SWRC version 3.00 beta, Piracicaba, SP, 2001</td>
</tr>
<tr>
<td>Available water content</td>
<td>AWC Difference between $\theta$ at 0.33 and 10 bars</td>
</tr>
<tr>
<td>Field water content</td>
<td>$\theta$ Gravimetric method</td>
</tr>
</tbody>
</table>

Statistical analyses: SAS GLIMIX procedure and post hoc Tukey HSD test
**INTRODUCTION**

**METHODS**

**RESULTS**

**CONCLUSION**

**AGRONOMIC IMPLICATIONS**

**LIMITATIONS**

---

**Fig.1.** Effect of biochar, tillage mode and production period on soil bulk density

- **Fertilizers applied in all plots:**
  - T1 = Straw
  - T2 = Corncob biochar (CCB)
  - T3 = Eucalyptus biochar (EB)
  - T4 = Straw + CCB
  - T5 = Straw + EB

**p=0.001**
**INTRODUCTION**

**METHODS**

**RESULTS**

**CONCLUSION**

**AGRONOMIC IMPLICATIONS**

**LIMITATIONS**

---

**Fig. 2.** Effect of biochar, tillage mode and production period on soil total porosity

- Fertilizers applied in all plots:
  - T2 = Corncob biochar (CCB)
  - T3 = Eucalyptus biochar (EB)
  - T1 = Straw
  - T4 = Straw + CCB
  - T5 = Straw + EB

Production period: $P = 0.004$
Fig. 3. Effect of tillage mode and production period on saturation, residual and available water content.
Fig. 4. Effect of biochar and its type on maize yield during each production period.

- **Fertilizers applied in all plots**
  - T1 = Straw
  - T2 = Corncob biochar (CCB)
  - T3 = Eucalyptus biochar (EB)
  - T4 = Straw + CCB
  - T5 = Straw + EB

- **Production Period 1**
  - T1: 3.5 t ha⁻¹
  - T2: 5.6 t ha⁻¹ (56% increase, p<0.01)
  - T3: 5.1 t ha⁻¹
  - T4: 5.4 t ha⁻¹
  - T5: 4.8 t ha⁻¹

- **Production Period 2**
  - T1: 2.8 t ha⁻¹
  - T2: 3.5 t ha⁻¹
  - T3: 3.2 t ha⁻¹
  - T4: 3.9 t ha⁻¹
  - T5: 3.4 t ha⁻¹ (54% increase, p<0.0001)
Both biochars applied at the rate of 15 t ha\(^{-1}\) had no significant effect on bulk density, porosity, hydraulic conductivity, available water content, water content at saturation and residual water content.

Flat plots had higher residual water content and water content at saturation compared to furrow-ridges plots.

During the second production period, porosity decreased; soil air entry point (\(\alpha\)) and available water content increased compared to the first period.
1. In the short run, farmers should not expect:

   a. Significant effect of low temperature biochars (250-300°C) on available water content in well drained oxisols with around 5% organic matter
      - Initial high hydrophobicity of such biochar
      - Initial high porosity of the soil.

   b. Significant difference in using straw instead of biochars or the combination of both in furrow-ridges, as far as soil available water content is concerned
2. In the short run, farmers:

a. Should not expect a different effect of biochar on soil physical parameters relatively to the tillage mode

➢ Thus, either tillage mode could be used with biochar by local producers, according to the topography of their land and their level of mechanization

b. Should expect significant increase in maize yield following biochar application for at least 2 production periods

➢ This could be due mainly to changes in soil chemical parameters
1. Biochar used was of similar size as soil particles, only one dose, manufactured at low temperature and tested in a relative short time frame.

   *Effect of biochar particle size and dose in the short and long term*

   *Effect of size and doses of medium to high temperature origin biochar*

2. No difference observed in using straw instead of biochars or the combination of both in furrow-ridges with reference to soil AWC.

   *Fate of biochar carbon in oxisols on GHG emissions in the short and long term (reported carbon sequestration could potentially justify the use of biochar instead of straw)*
ACKNOWLEDGEMENTS

• My Directors Prof. MUNSON and Prof. ALLAIRE

• The Congo Basin Natural Resources Management Training Program

• The Queen Elizabeth's Scholarship program

• Research Professionals: Marie Coyea, Sebastien Lange, Alain Brousseau, and Daniel Marcott of Laval University

• All my laboratory colleagues in Forestry and in Agriculture

• The University of Dschang and all my PEOGRN-BC colleagues

• Prof. Mvondo Zé and M. BOUKONG (soil chemistry and soil physics laboratory FASA)

• All those who helped in the biochar making process and in field work in Cameroon
Thank you!

Questions

Effects of Biochar on Physical properties of an oxisol