Agronomic benefits and detriments of using biochar

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Agronomic benefits and detriments of using biochar

Carlo Grignani,
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University of Turin

Engineering Conferences International
Biochar: Production, Characterization and Application

Alba, August 20-25, 2017
The traditional vision of biochar

Lehmann et al. 2006, Mit. Adapt. Strat. Global Change
Lehmann 2007, Nature Commentary
The traditional vision of biochar

- Give value to wastes: sanitisation, use by-products of renewable-energy, waste management
- Reduce problems of contaminated soils
Why farmers do not ask for more biochar? Is it “only” science?

...all that glitters is not gold
Biochar papers in Scopus

5651 papers on BIOCHAR (since 2000)

3294 papers on BIOCHAR + SOIL

• China 40
• USA 32
• Australia 24
• India 15
• Germany 12
• Pakistan 12

1033 papers on BIOCHAR + CROP + LONG-TERM (since 2009):

Lack of field or farm research and of long term studies
Biochar influences soil and crop

- C addition
- C sequestration
- pH increase
- Nutrient addition
- Increase in soil surface area and Cation Exchange Capacity
- Improvement of soil porosity
- Protected habitat for microorganisms
- Improvement of soil aeration
- Increased mineralization
- Increased availability of nutrients
- Improvement of soil water holding capacity
- Increased plant growth

Subedi et al., 2017
**Expected Benefits to Plants**

Due to improved soil physical characteristics:
- Available water, aeration, root penetration

Due to improved soil chemical characteristics:
- Improved availability of nutrients

Due to improved soil biological characteristics:
- Soil microorganisms ensure better nutrient availability

Due to direct nutrient addition:
- Improved availability of nutrients

Due to indirect effects on soil biota:
- Improved microbiology and resistance to soil born pathogens
Application of biochar and Crop response: a complex system

variability of biochar characteristics

variability of soil characteristics

variability of crop characteristics

variability of management practices

Crop response is difficult to predict

Subedi et al., 2017
Pyrolysis Conditions affects biochar

<table>
<thead>
<tr>
<th>Parameters that increase at increasing Pyrolysis Temperature</th>
<th>( \text{PT} &gt; 500 \degree \text{C} ) due to loss of acidic functional groups</th>
<th>( \text{PT} &gt; 600 \degree \text{C} ) due to collapse of pore and surface structures</th>
<th>( \text{PT} &gt; 600 \degree \text{C} ) due to collapse of pore structure</th>
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</thead>
<tbody>
<tr>
<td>CEC</td>
<td>up to 500 \degree \text{C}</td>
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<tr>
<td>Porosity</td>
<td>up to 600 \degree \text{C} (anti-clogging of pore space)</td>
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<tr>
<td>Surface Area</td>
<td>up to 600 \degree \text{C}</td>
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<tr>
<td>P recovery</td>
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<tr>
<td>Ash content</td>
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<td>pH</td>
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<td>( \text{Ca}^{2+}, \text{Mg}^{2+}, \text{K}^+, \text{Na}^+ )</td>
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<tr>
<td>Heavy metals</td>
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<tr>
<td>Biochar yield</td>
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<tr>
<td>C recovery</td>
<td></td>
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<td>N recovery</td>
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<td>S recovery</td>
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<td>Surface acidity</td>
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<td>Surface Area</td>
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</tr>
</tbody>
</table>

However, biochar characteristics are not always easy to predict for agronomic use! Give farmers homogeneous quality groups of biochar.
Feedstock type affects biochar

Structure vs Nutrient

Modified from Subedi et al., 2017
Feedstock types

• Bioenergy Crops: no
• Crop, food or wood wastes, agroindustry by-products: Yes
• Manure: to improve transferability from excess
• Other wastes: ?
• In all cases: sufficient quantity and quality
Application of biochar and Crop response: a complex system

Variability of biochar characteristics

Variability of soil characteristics

Variability of crop characteristics

Variability of management practices

Crop response is difficult to predict

Subedi et al., 2017
Crop response to biochar and soil pH
Crop productivity as a percentage of the control for five pH soil classes (n. comparisons/n. publications)

Other effects associated to soil texture: sandy soil more reactive than finer soils (water effects, particle larger surface area)

Application of biochar and Crop response: a complex system

- Variability of biochar characteristics
- Variability of soil characteristics
- Variability of crop characteristics
- Variability of management practices

Crop response is difficult to predict

Subedi et al., 2017
Different Crop responses to biochar
Crop productivity as a percentage of the control for some wide spread cultivated species

Need for field research on crop effects

Tropical vs temperate biochar effects on crops

Crop productivity as a percentage of the control

Application of biochar and Crop response: a complex system

- Variability of biochar characteristics
- Variability of soil characteristics
- Variability of crop characteristics
- Variability of management practices

Crop response is difficult to predict

- Amount
- Interaction with fertilization
- Incorporation depth
- Timing
- Particle size
- Interaction with tillage
- Elapsed incorporation time
- Type of experiment
- Environmental conditions

Subedi et al., 2017
Crop response to biochar application rates
Crop productivity as a percentage of the control (meta-analysis of 782 replicates in 177 treatments)

Response to biochar-fertiliser interactions
Crop productivity as a percentage of the control (meta-analysis of 7632 replicates in 172 treatments)

Threats to agricultural use

Direct addition of toxic compounds for soil life

• Volatile organic compounds (VOCs)
• Polycyclic aromatic hydrocarbons (PAHs)
• Polychlorinated benzenes (PCBs)
• Heavy metals
• Excessive salinity (Na\(^+\))

Excessive liming effect (in alkaline soils)

Immobilization

• Absorption of pesticides
• Absorption of metals (imbalance in plant nutrition)

Production of dust at application

Subedi et al., 2017
Major problem: heavy metals

Several biochars in the scientific literature do not respect quality standards

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<tr>
<td>Cd</td>
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<td>11%</td>
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</tr>
<tr>
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<td>7%</td>
<td>3%</td>
<td>29</td>
</tr>
<tr>
<td>Cu</td>
<td>45%</td>
<td>38%</td>
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<tr>
<td>Pb</td>
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<tr>
<td>Mn</td>
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<td>0</td>
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</tr>
<tr>
<td>Mo</td>
<td>80%</td>
<td>0</td>
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<tr>
<td>Ni</td>
<td>16%</td>
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<td>51%</td>
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<tr>
<td>PAH</td>
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<td>0</td>
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</tr>
</tbody>
</table>

Subedi et al., 2017
Is Biochar really climate-friendly?

C sink

What about GHG?
In most cases biochar mitigates $N_2O$ emissions.

Fig. 2. Mean change in $N_2O$ emissions depending on the reported temperature of pyrolysis (a) and the type of pyrolysis (b). Symbols represent mean effect sizes (percentage of change in $N_2O$ emitted) with 95% confidence intervals (Rosenthal’s Fail Safe N: 9824 and 7004 for (a) and (b) respectively). The numbers shown in parentheses correspond to observations in each class upon which the statistical analysis is based. The dotted line indicates the mean effect size for all temperatures (a) and type of pyrolysis (b).
it depends on biochar properties
Conclusions

Effects on soil and crop
• Generally positive, but very variable; need for biochar characterization
• Better acidic and sandy soil; better for tropical conditions
• Need for long term studies, need for information on management

Effects on soil life
• Variable but not negative

Effects on the environment
• Positive for GHG, but not for “nutrient biochar”
• Questionable for HM and some organic compound

Effects on the agro-systems
• Biochar availability: only wood derived biochar?
• Biochar does not exist: biochar$ exist
• Biochar acceptability (use of wastes, need for engineering energy production)
• Longevity effects of biochar applications: almost unknown
Thank you for your attention

Frontiers special issue

Frontiers will be launching a series of Research Topics for *Waste Management in Agrosystems section*

Prof. Lars Stouman Jensen (DK) and Carlo Grignani (I) coordinate the topic *End-user requirements for recycling, bio-based fertiliser products*

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