Land-Use Challenges

Tilman et al. 2002, Nature 418
• Humans currently appropriate more than a third of the production of terrestrial ecosystems and about half of usable freshwaters

• Have doubled terrestrial nitrogen supply and phosphorus liberation

• Have manufactured and released globally significant quantities of pesticides

• and have initiated a major extinction event.

Tilman at al. 2001, Science 292
Land-Use Challenges
Fertilizers

Tilman et al. 2002, Nature 418
Land-Use Challenges

During the next 50 years the global population will grow by 50% and the population is more demanding → doubling food production

Predictions:
• A further conversion of $10^9$ hectares of natural ecosystems (loss of natural ecosystems larger than the United States)

• 2.4 to 2.7-fold increases in nitrogen and phosphorus-driven eutrophication of water.

Tilman at al. 2001, Science 292
Land-Use Challenges/Limitations

How can agricultural productivity doubled?

• Without increasing the environmental impact
  
  • Considering climate change
  
  • Considering peak oil
    In developed countries 4kcal of energy is invested to produce 1kcal of food (Pimentel 2009)
    One barrel of oil per hectare (Hall and Hall, 1993)
  
  • Considering peak phosphorus
  
  • Considering soil degradation
    Average soil loss in the US is 5 tons per ha per year (Horrigan et al. 2002)
  
  • Considering water shortages
  
  • Considering loss of biodiversity
    In the past 15 years 1500 rice varieties disappeared in Indonesia (Horrigan et al. 2002)
Land-Use Challenges/Limitations

Peak phosphorus
Cordell et al. 2009, Global Environmental Change

peak oil “Hubbert’s Peak”
Nutrient flow management “dead zone” in the Gulf of Mexico
“A greener revolution is needed”

Tilman et al. 2001, Science

What is needed

• Soil conservation
• Closing nutrient cycles
• Material flow management involving nutrients and carbon
• Higher nutrient use efficiency

• Climate change mitigation and adaptation
European example the Plaggen (Plaggic Anthrosols)

Addition of sods mixed with farmyard manure
Anthrosols Brazil – Terra Preta

Photo: Ilse Ackermann
Charcoal Terra Preta
Modern agriculture outside markets
Biochar
Opportunities and Challenges

Bioenergy, carbon sequestration and sustaining soil fertility seems feasible

- Only a proportion of the carbon used for energy
- Proportion used to sequester carbon
- and improve soil fertility
Charcoal Carbon Sink - Traditional Knowledge

Long lasting carbon sequestration

Lehmann et al. 2006

![Graph showing carbon remaining in years for bio-char and un-charred organic matter.](image)
Historic Biorefining
Traditional Use US (1847)

Elad et al. 2010, Phytopathology

“Charcoal absorbs and condenses the nutritive gases within its pores.”

Charcoal often checks rust in wheat, and mildew in other crops

“Ammoniacal liquor holds large quantities of nitrogen,....charcoal dust may be added, ..the charcoal soon combine with the ammonia, ..it is a powerful manure,”

“Guano should be mixed with twice its bulk of charcoal dust”

“Charcoal should be added to liquid manure to absorb the ammonia”

“Poudrette is the name given to the human faeces after they have been mixed with charcoal dust..”

“A dressing of charcoal has in many instances, been found so beneficial that it has been extensively introduced in France for the wheat crop”

“The turnep (Brassica rapa.) Charcoal dust applied in the same way has been found to increase the early growth from four to ten-fold.”

Danny Day and others
Slash and Char as Alternative to Slash and Burn

~50% of C remains as charcoal

~2% of C remains as charcoal
Biochar Research Terra Preta Nova

EMBRAPA research station Brazil
Biochar

Crop Response

Steiner et al. (2008), Plant and Soil, n=5, means and SE
Biochar
Crop Response

Plants after 55 days

NPK fertilizer & charcoal  NPK fertilizer without charcoal
Research results, increased N recovery

Steiner et al. (2008), J Plant Nutr Soil Sci, n=5, means and SE
Poultry litter stabilization, pathogen and odor reduction

**Ash (complete combustion)**
- high concentration of minerals (P, K, Ca, Mg,)
- Loss of nitrogen (N)

**Biochar (pyrolysis, carbonization)**
- concentration of minerals (P, K, Ca, Mg,)
- 70% of N lost (400 °C depending on temp.)

**Compost (composting)**
- Concentration of minerals (P, K, Ca, Mg,)
- Loss of nitrogen (NH3 volatilization, 70 – 88%, Ogunwande et al., 2008)
## Biochar Nutrient Contents

<table>
<thead>
<tr>
<th>Material</th>
<th>pH</th>
<th>C</th>
<th>N</th>
<th>P</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poultry Litter</td>
<td>9.74</td>
<td>392</td>
<td>30.9</td>
<td>35.9</td>
<td>58.6</td>
</tr>
<tr>
<td>Peanut Hulls</td>
<td>10.1</td>
<td>804</td>
<td>24.8</td>
<td>1.97</td>
<td>16.4</td>
</tr>
<tr>
<td>Pine Chips</td>
<td>8.30</td>
<td>817</td>
<td>2.23</td>
<td>0.14</td>
<td>1.45</td>
</tr>
</tbody>
</table>
Nitrogen fertilization efficiency

In addition one unfertilized control

1.5 Mg ha$^{-1}$ (52.5 kg N ha$^{-1}$)
3 Mg ha$^{-1}$ (105 kg N ha$^{-1}$)
6 Mg ha$^{-1}$ (210 kg N ha$^{-1}$)

Mineral fertilizer (MF) based on PL

Poultry litter (PL)

Carbonized PL (PLc)

MF based on PLc

MF = NH$_4$NO$_3$
KCl
CaHPO$_4$
and MgSO$_4$
Nitrogen fertilization efficiency

Five plants per pot, 4 replicates
First harvest 72 days after planting, thereafter once a month for 3 consecutive harvests

Chromi-Alumic Acrisol = Fine, kaolinitic, thermic Typic Kanhapludults
Results N uptake in relation to N fertilized

\[ y = 0.244x + 88.97 \]  
\[ R^2 = 0.977 \]

\[ y = 0.005x + 93.09 \]  
\[ R^2 = 0.028 \]

\[ y = 0.723x + 78.40 \]  
\[ R^2 = 0.996 \]

\[ y = 0.697x + 88.49 \]  
\[ R^2 = 0.999 \]
Char it!

Biochar
how to make
clean energy and
biochar from
chicken sh...

Char it!
Char it!
Char it!

http://www.sjroe.com
Biochar as Bulking Agent in composting
Faster decomposition increased respiration
Reduced Nitrogen Losses with 20% biochar

Ammonia emissions reduced by up to 64%

Total N losses reduced by up to 52%
Compost with and without biochar

0% biochar

20% biochar

20% biochar