AN INTRODUCTION TO BIOCHAR FOR ENVIRONMENTAL MANAGEMENT

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Source material: Lehmann, J and Joseph, S. 2014. A Biochar Classification System and Associated Test Methods. In: Biochar for Environmental Management - Science and Technology, 2nd edition. J. Lehmann and S. Joseph (eds.). Earthscan, and references therein.

Biochar for Environmental Sustainability and Economic Development

SANTIAGO DE COMPOSTELA, JUNE 26-28

International Biochar Initiative

CSIC

THE UNIVERSITY of EDINBURGH

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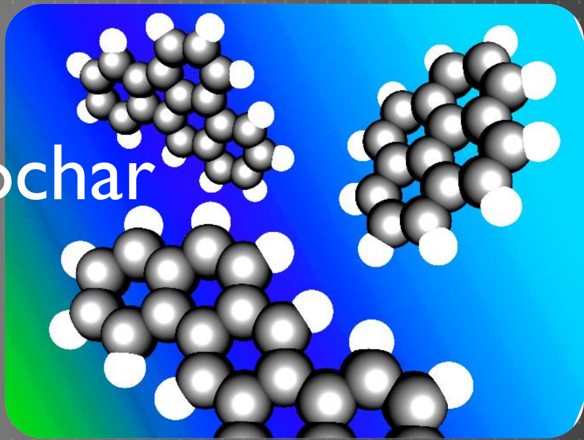
What is biochar

- A product of heating biomass in the absence of, or with limited air, to above 250°C
- Through the process of ***charring or pyrolysis***
- Distinguishes itself from charcoal or other carbon products in that it is ***intended for use as a soil application or more broadly for environmental management***
- Important defining feature is a certain level of organic C forms, called ***fused aromatic ring structures***

Properties of biochar

- Chemical properties of the organic C structure of biochar is fundamentally different from feedstock
- Fused aromatic rings are key to biochar properties
  - → **mineralization and adsorption**
- But macro-morphological characteristics of biochars typically resemble those of feedstocks
  - i.e., typically looks the same but is black in color



Nomenclature

- **Biochar**: the solid product of pyrolysis designed to be used for environmental management.
  - IBI definition : "A solid material obtained from thermochemical conversion of biomass in an oxygen-limited environment”
- **Pyrogenic carbonaceous material (PCM):** the umbrella term for all materials that were produced by thermochemical conversion and contain some organic C
  - E.g. charcoal, biochar, char, black carbon, soot, activated carbon

Nomenclature (continued)

- **Charcoal:** produced by thermochemical conversion from biomass (mainly but not exclusively wood) for energy generation
- **Black carbon:** term is extensively used in the atmospheric, geologic, soil science and environmental literature to refer to PCMs dispersed in the environment from wildfires and fossil fuel combustion
- **Ash:** mineral fraction of biomass or PCM (according to ASTM D1762-84) and typically includes metals, their oxides and carbonates (Enders et al, 2012)

Brief history of biochar research and application

- Several centuries of documented interest in adding biochar to soils for plant productivity
- Scientific publications beginning in the 1800s and into the early to mid-1900s
- Thereafter drop in activity likely due to large-scale development and marketing of chemical fertilizers


Image courtesy of http://blogs.extension.org/mastergardener/tag/agriculture/

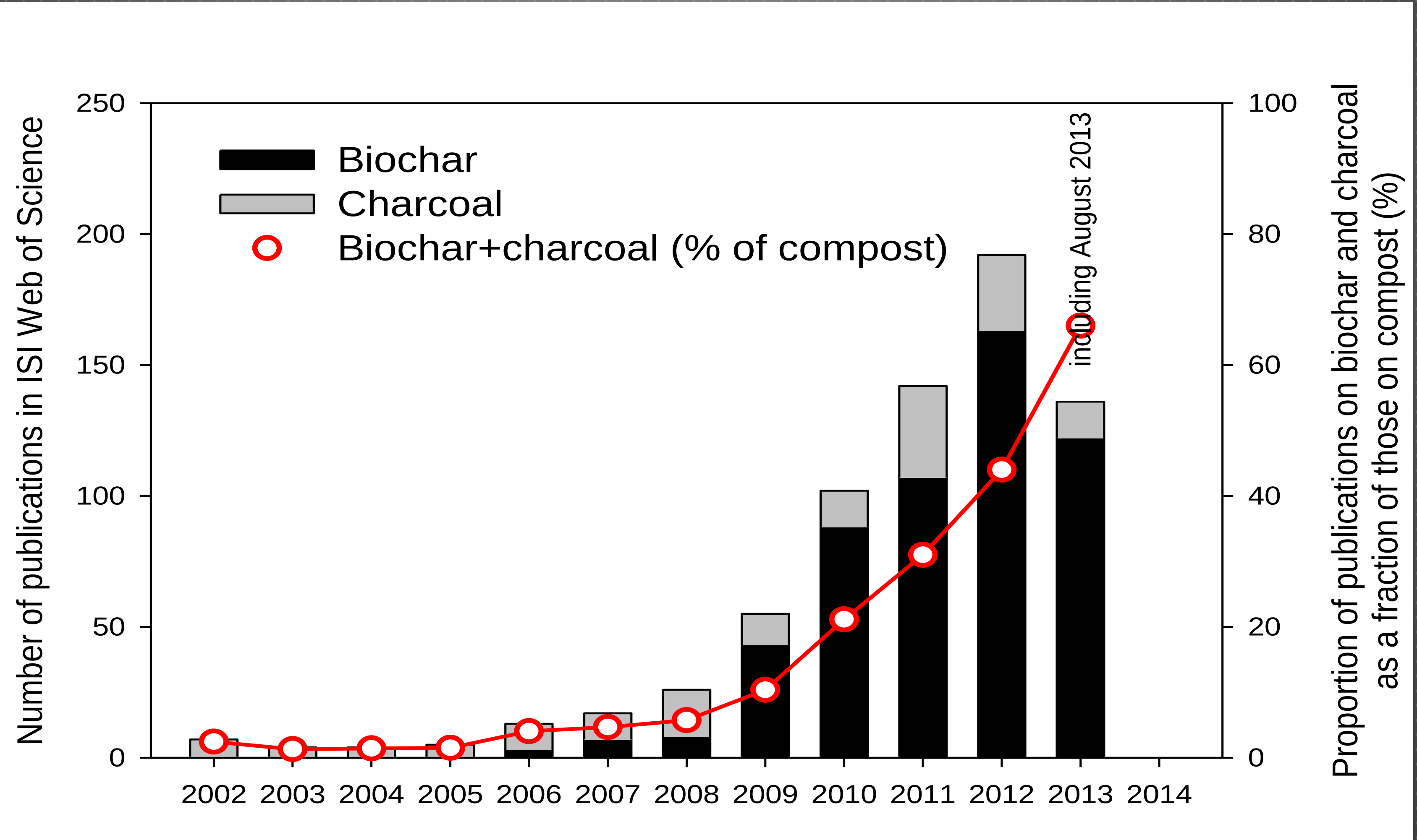
Terra preta de indio soils renew interest

- Amazonian dark earths (*terra preta de indio*)
  - Soils in the Amazon Basin created by Amerindian populations
  - 100s – 1,000s of years old
  - Enriched with biochar-type material and highly fertile
- Term "**biochar**" introduced only within last 10 years to:
  - Distinguish from activated carbon made from fossil fuel and activated carbon made from biomass (Bapat et al, 1999), and
  - Replace the term "charcoal" as a fuel (Karaosmanoglu et al, 2000) and to distinguish it from coal

www.biochar-international.org

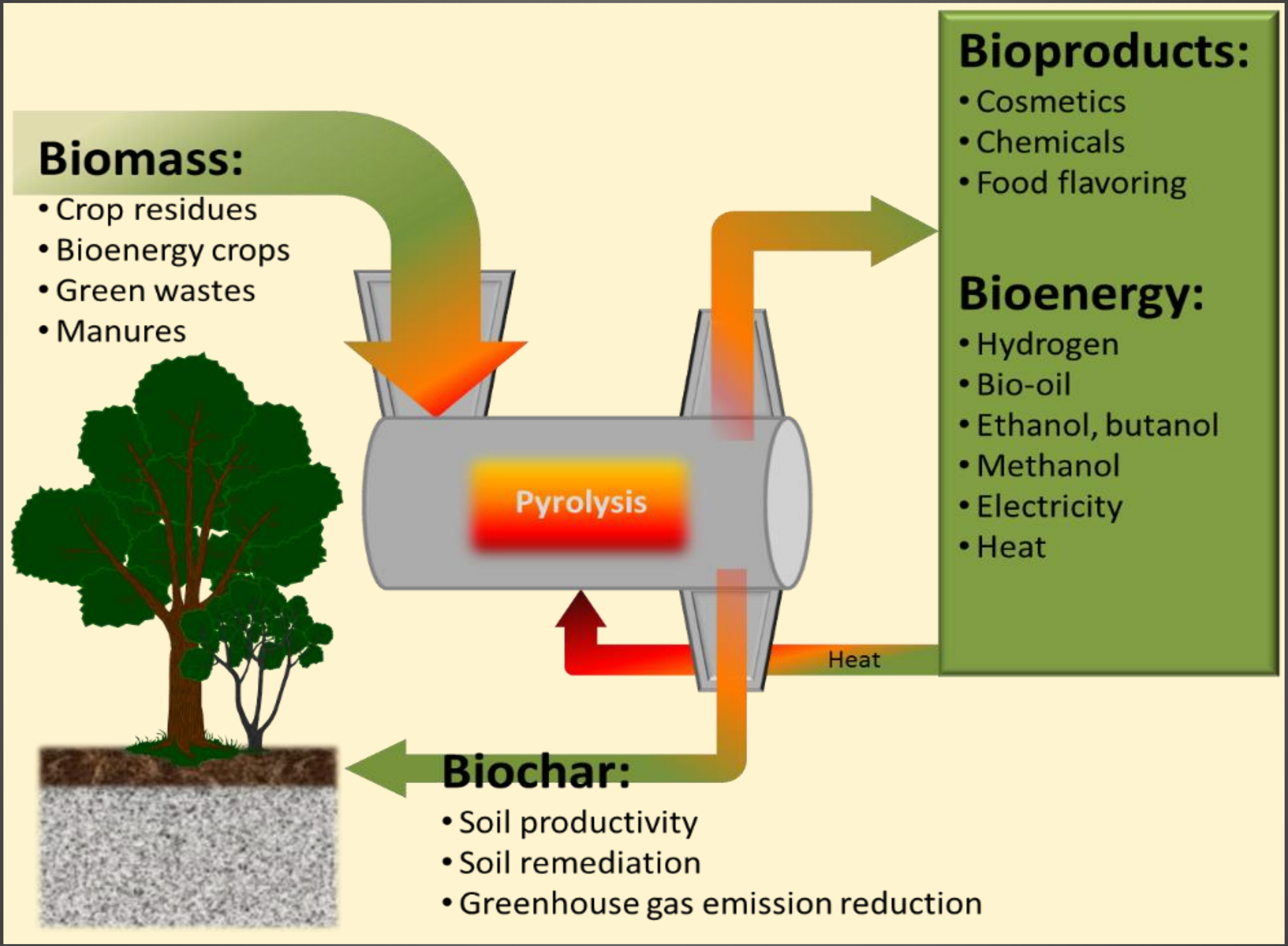
Research activity spikes in last decade

- In early 2000s mostly focused on *terra preta*
- 2008 → biochar-specific publications

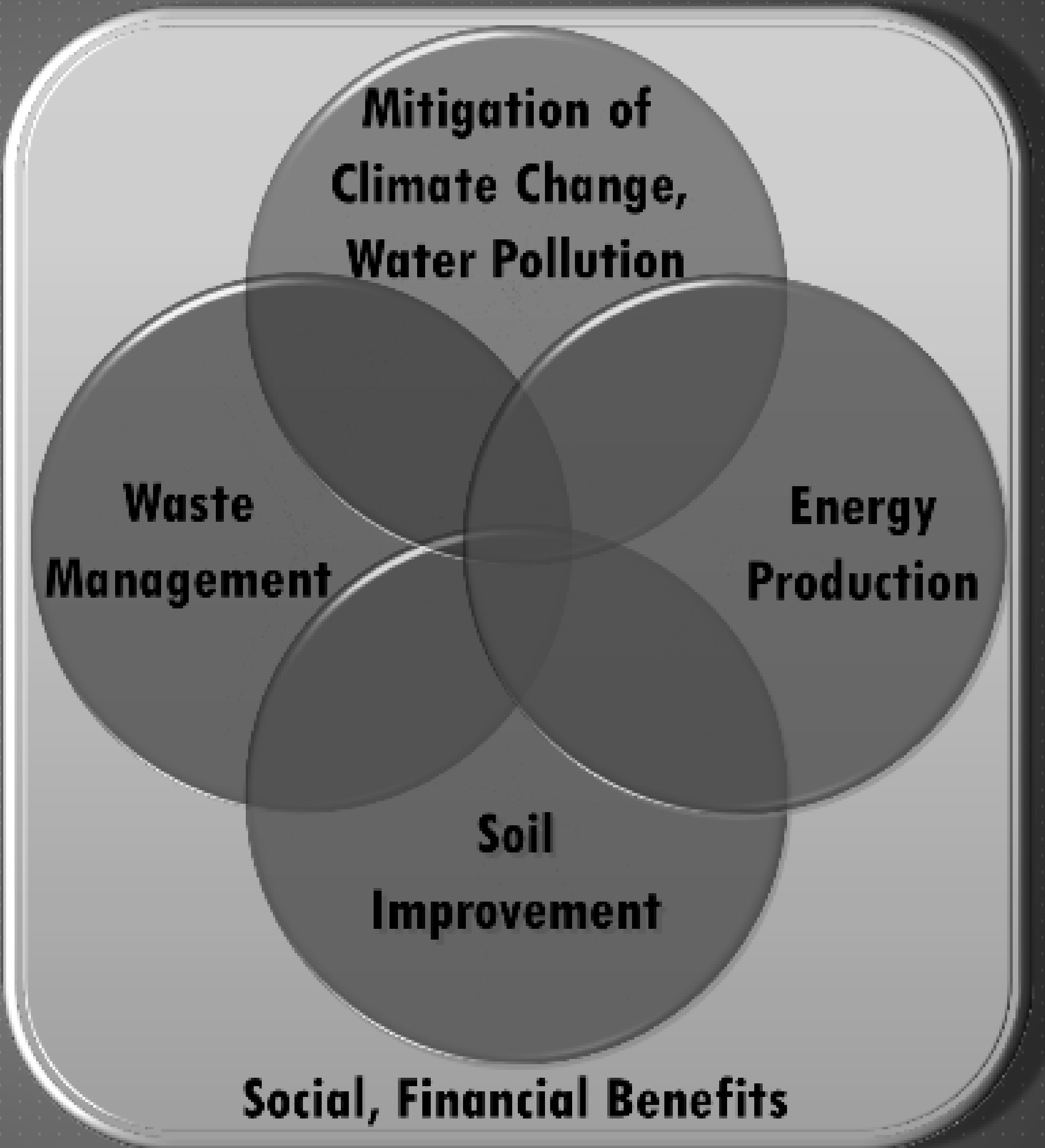


Biochar as a system

- *Biochar* is a term for a **spectrum of materials**
- Benefits from biochar production and use only realized in a **systems approach** to managing the environment
  1. Feedstock procurement → biomass systems
  2. Pyrolysis → energy production and use systems
  3. Biochar use →
     a) Soils, land use
     b) Climate change
     c) Waste management


Biomass:
• Crop residues
• Bioenergy crops
• Green wastes
• Manures
Pyrolysis
Bioproducts:
• Cosmetics
• Chemicals
• Food flavoring
Bioenergy:
• Hydrogen
• Bio-oil
• Ethanol, butanol
• Methanol
• Electricity
• Heat
Heat
Biochar:
• Soil productivity
• Soil remediation
• Greenhouse gas emission reduction

4 COMPONENTS OF A BIOCHAR SYSTEM



Soil improvement

- **The defining feature of biochar systems**
- **Targets →**
  - crop productivity through improvements of soil nutrient availability
  - soil physical properties, specifically water relations
  - plant-microbe interactions
  - soil remediation

Soil improvement

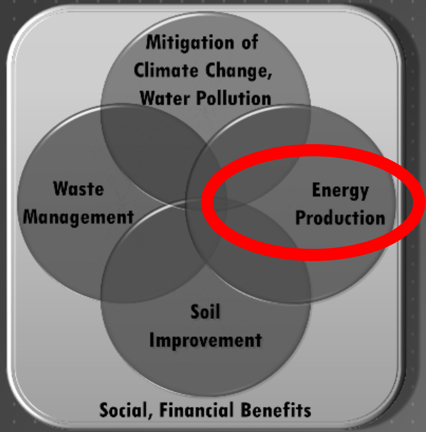
- But biochar is a **spectrum of materials** with very different effects in soils
- Need to **classify** biochars to distinguish physical-chemical properties
- Critical to communicate biochar effects with consumers, regulators, agronomists, etc.

Climate change mitigation

- Biochars have lower mineralization (fused aromatic C rings) as compared to the original material
- →reduces CO_2 emissions from the system and is key to climate change mitigation with biochar
- But…dependent on feedstocks
  - E.g., old growth forest vs crop waste residues deliver very different carbon balance
- And, emissions throughout system life cycle impact the GHG budget including
  - Nitrous oxide, methane from soils or biomass
  - Transport, infrastructure, land use change

Waste management

- Pyrolysis of wastes is well-established
- Technology can handle a wide range of materials
  - Woody biomass, agricultural residues, manures, sludge, etc.
- Must ensure **safety and utility** of biochars produced from wastes



Energy production

- Pyrolysis has been used to produce energy for more than 100 years
- Heat energy
- Also, liquid and gaseous byproducts can be refined for energy or other uses
  - Bio-oils
  - Syngas
- Trade-off between energy vs biochar maximization

Current state of biochar: Research gaps

- Scientific output is high but commercialization is lagging
- Knowledge gaps
  - Decision tool to identify typologies that match specific biochars with soil and crop needs
  - Comparisons between biochar and other organic amendments e.g. compost
  - Large-scale, long-term *in situ* experiments

Current state of biochar: Commercial applications

- Need to understand, communicate benefits as well as potential negative impacts
- Comply with
  - Best management practices
  - Policies, regulations governing emissions, feedstocks, biochar land application, etc
- Understand trade-offs between system components
  - E.g., soil improvement vs sustainable energy generation
- Likely need social, economic incentives
- Need for large-scale commercial biochar enterprises to predict viability of biochar as an environmental management strategy