The Basics of Biochar

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Warm Heart Foundation prepared this introduction to biochar for the use of farmers in the developing world. It digests and simplifies a huge amount of complex, technical information that is incomprehensible or irrelevant to most small farmers.

We have done our best to ensure that this manual is accurate, but we have ignored a great deal of nuance. Please remember that our audience cannot read or write, has no formal agricultural training, does not have any money, and is focused almost exclusively on the short-term.

Our approach is tailored to the realities facing small farmers and presents biochar so that it makes sense to them. In the Introduction, we refer to the bigger picture, but only in passing. This manual is for farmers who lack the cash and secure land tenure to invest in the long-term, and who rationally see no reason to engage in costly efforts on their own to address global concerns.

Just to be clear

When we talk about biochar, we mean this…

…not this.

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Introduction

Why Biochar?

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Biochar benefits everyone

- Biochar is powerful stuff! It can:
  - Reduce water needs and increase crop yields;
  - Reduce costs if you use chemical fertilizer;
  - Reduce smoke during the burning season and improve your children's health;
  - Reduce pesticide poisons in your soil and water;
  - Reduce your country's dependence on foreign oil and chemical suppliers; and
  - Reduce green house gas emissions and increase your ability to cope with climate change.

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Biochar benefits you and your family

- Biochar can save you money and make you money.
- Biochar fertilizer can:
  - Reduce the money you spend on NPK fertilizer;
  - Reduce the money you spend on pesticides;
  - Increase your crop yields;
  - Improve your soil; and
  - Increase your soil's ability to hold water.
- You can sell it, too!

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Biochar benefits your community

- Biochar can improve your family's and your community's health and quality of life
- By making biochar out of field waste you stop smoke while making a valuable product
  - Making biochar produces no smoke
  - With less smoke, everyone will feel better; and
  - Fewer infants and elders go to the hospital with breathing problems – or die
- Biochar soaks up poisons in your soil and water that cause cancer and birth defects

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Biochar benefits your country

- Your country must import fertilizer or the chemicals used to make fertilizer.
- It must import energy to make and distribute fertilizer.
  - Biochar reduces your country's dependence on foreign suppliers.
- Your country spends ***big*** money to care for people hospitalized because of smoke and pesticide poisoning.
  - Biochar reduces the annual health costs of smoke and helps to eliminate pesticides.

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Biochar benefits the whole world

- Biochar production and use slow climate change:
  - Field burning of agricultural wastes is a major source of green house gases; and
  - The smoke produced adds to global warming.
- Biochar fertilizer actually reduces green house gases
  - It captures CO_2 removed from the air by plants and permits it to be buried underground.
- Slowing global warming protects your crops and reduces storms and floods that damage them.

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Section I

What Is Biochar?

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The simplest definition

- Biochar is charcoal you bury in your soil to improve crop yields.

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There is nothing new about biochar

- People around the world having been making biochar for thousands of years and still are today




- You can make charcoal lots of different ways and you can apply it in lots of different ways. They all work.

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What it replaces: Open field burning

- Who cares?
  - Field fires produce lots of particulates (smoke), green-house gases, ash
- Agricultural benefits?
  - None
- Soil enrichment?
  - Zero
- Soil sterilization?
  - Zero

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A slightly better definition

- Biochar is charcoal made in an oxygen restricted container and then buried in your soil to improve crop yields.

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Drawbacks to traditional systems

- Traditional methods and charcoal kilns are:
  - Slow – they can take days!
  - Smoky
  - Make lots of worthless ash
  - Inefficient – 7-10%

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Pyrolysis: The magic word

- Biochar is biomass ***pyrolyzed*** in an oxygen restricted container and then buried in your soil to improve crop yields.

Smokeless, GHG-less pyrolysis of corn stalk into biochar

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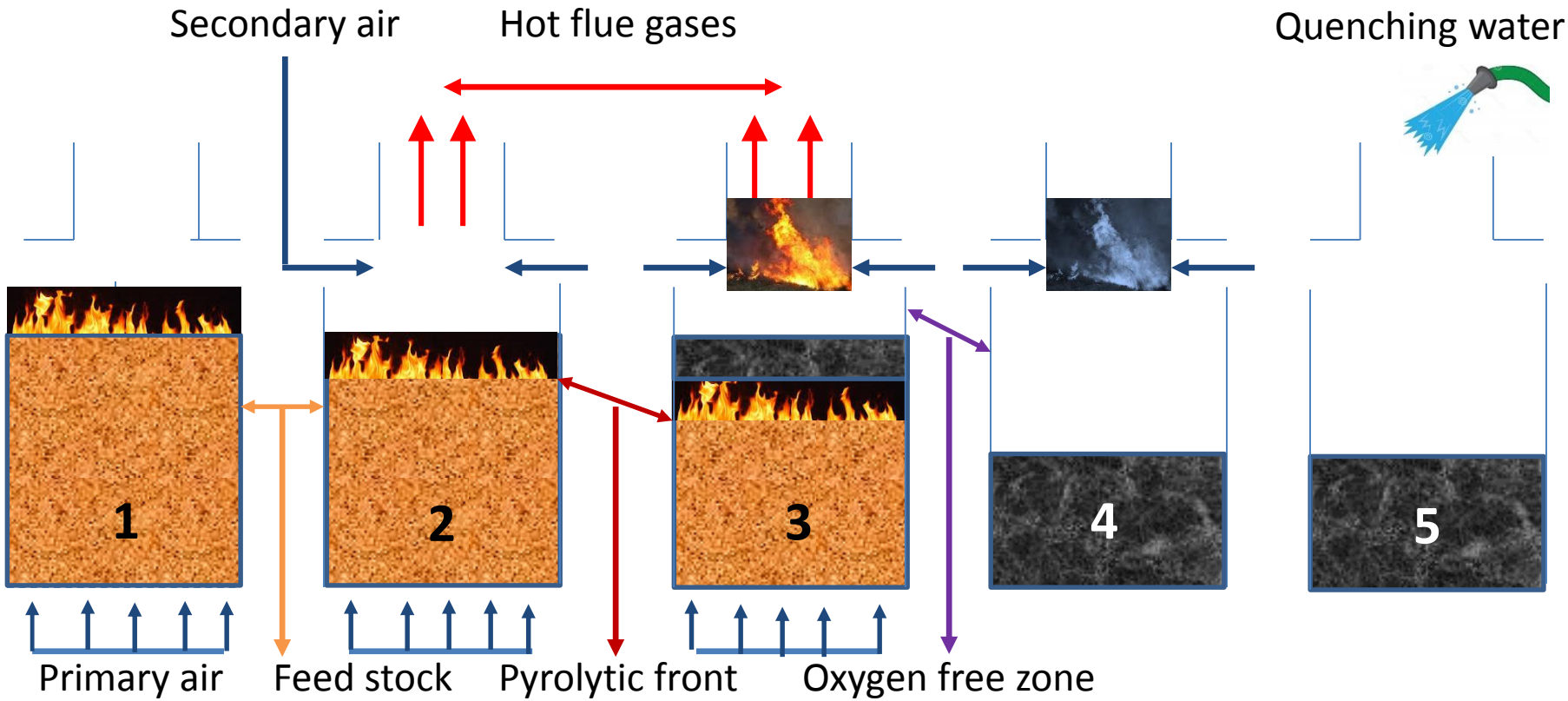
Basic pyrolysis



1. Feed Stock is lit from the top (Top Lit), drawing air in from the bottom(Up Draft).
2. Heat produces pyrolytic front.
3. Heat of downward moving pyrolytic front releases gases (volatiles) from feed stock which mix with secondary air and burn orange. Burning eliminates particulates and GHGs
4. Process continues in almost completely oxygen free environment until volatiles are consumed. Flame changes to blue/purple.
5. We quench finished biochar with water.

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Critical improvements with pyrolysis

- Virtual elimination of smoke (particulates)
- Virtual elimination of GHG emissions
- Sharp reduction in ash
- Sharp increase in efficiency: from 7-10% with charcoal type kilns to 30-35% with biochar kilns
- Increase in process speed from days to hours

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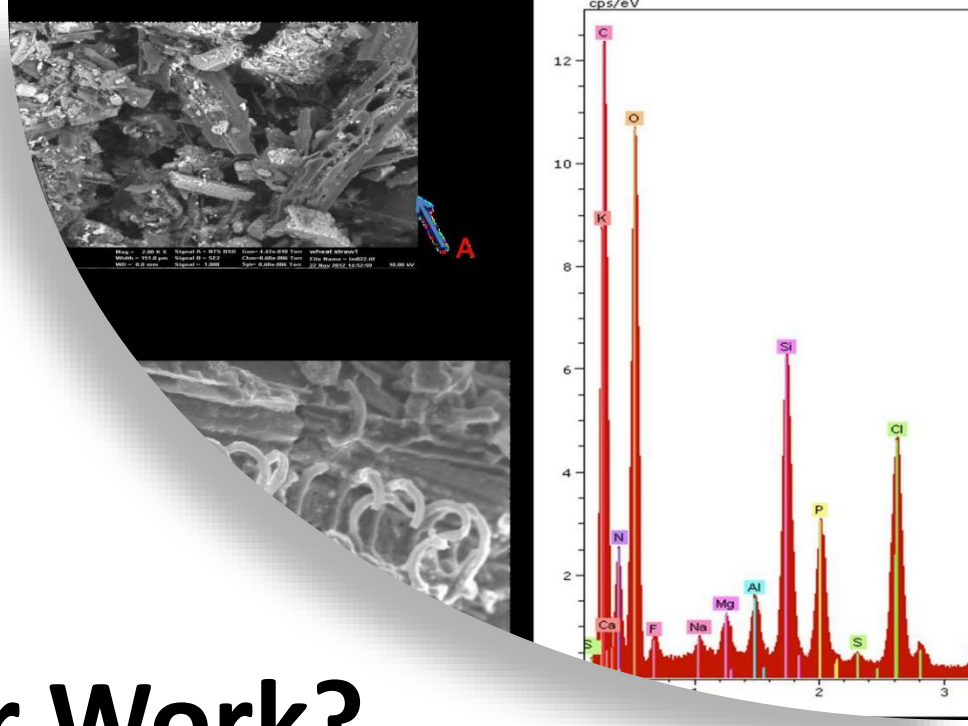
Section II



How Does Biochar Work?

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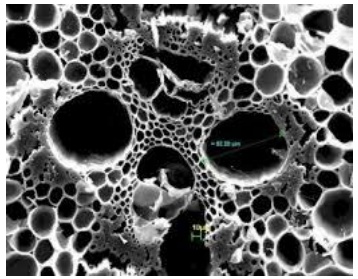
Electricity and tiny holes

- Biochar has billions of tiny tiny and just tiny holes resulting in a hgue surface area
  - These holes give biochar the capacity to absorb huge amounts of liquids
- Biochar's surface is electrically charged
  - This attracts elements that attach to it
  - Molecules enter the smallest holes, react chemically and become part of the biochar



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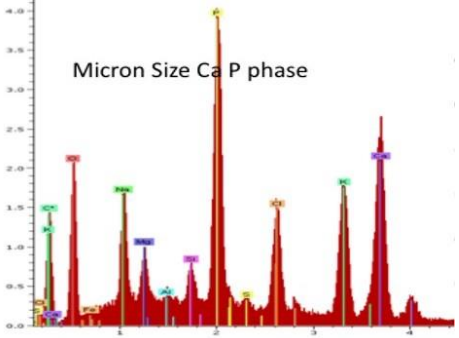
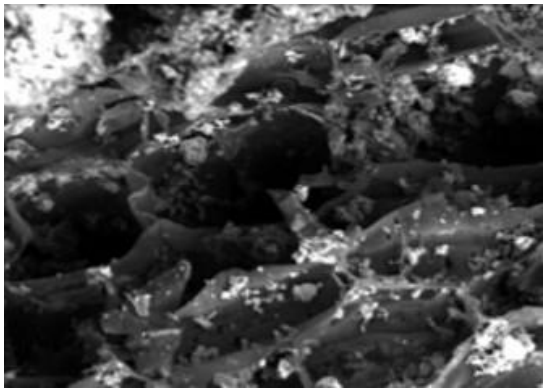
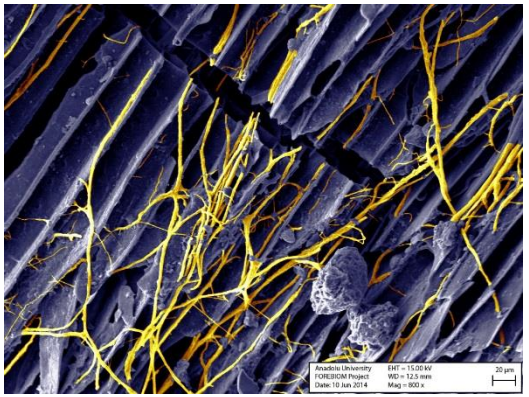
Every peak in this sample spectrum is a different element

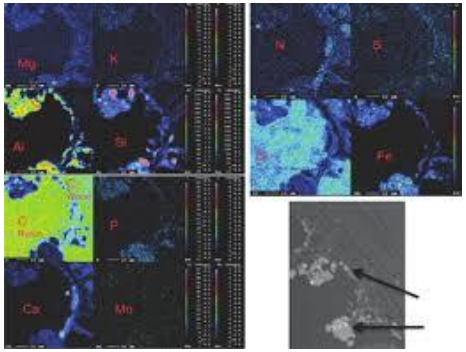




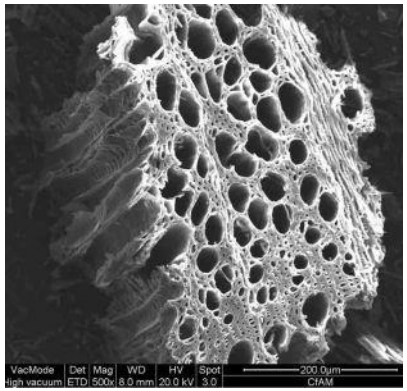
In soil, biochar particles adsorb minerals from all around becoming mini fertilizer chips.



Each color in this electron microscope image is a different element



In this electron microscope image you can see tiny life forms colonizing the surface of a biochar particle



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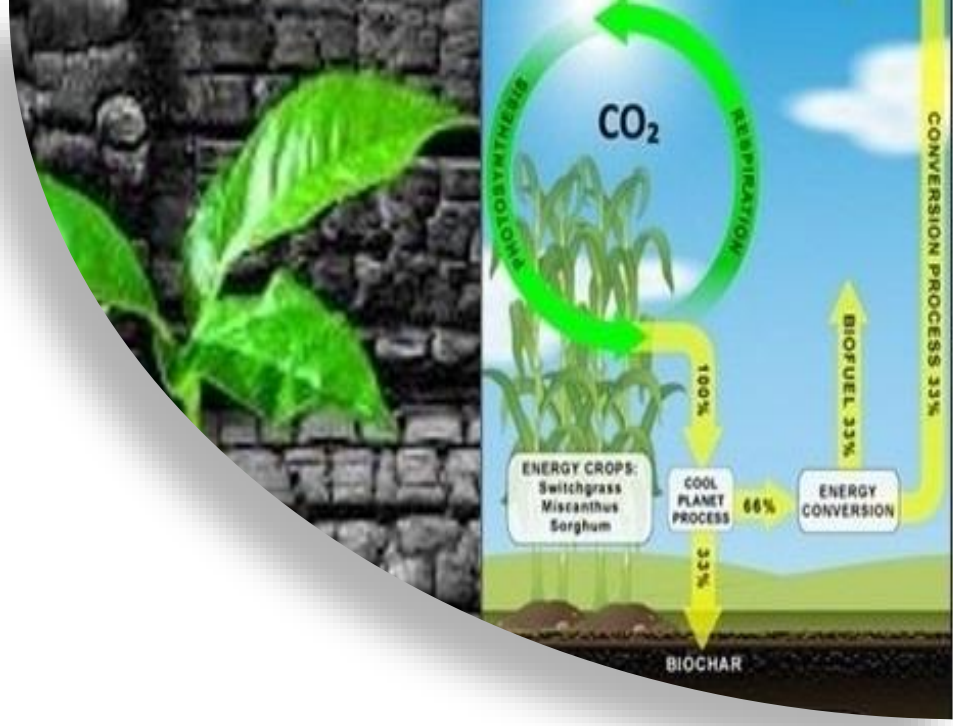
Section III



What Can Biochar Do For You?

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Biochar is great stuff!

- Biochar will improve your soil in five ways:
  - Raise the pH – the single most important thing you can do to increase yields with our acidic soils
  - Collect essential nutrients for your crops
  - Encourage soil microbes, fungi and earth worms
  - Retain water in your soil
  - Help your crops to fight diseases

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Which one had biochar?

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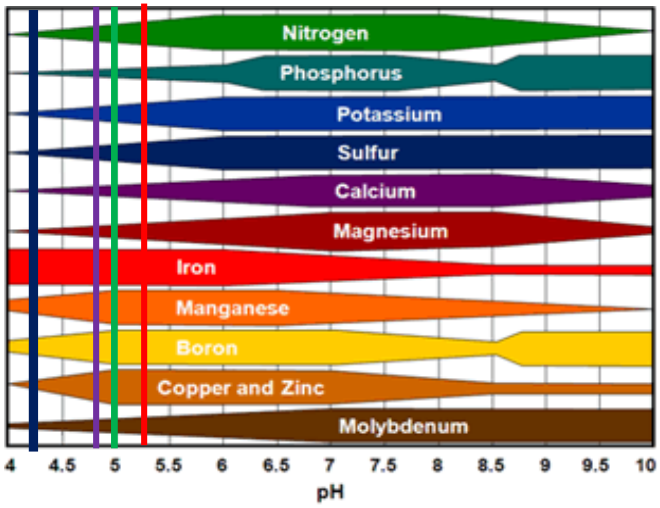
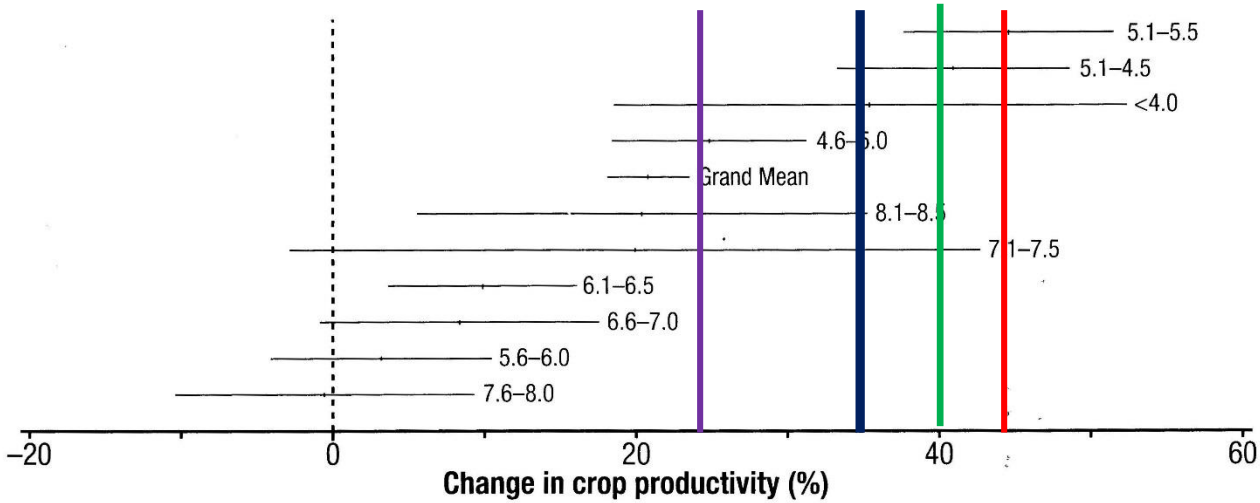
Raising pH

- Our soils are very acidic – pH as low as 4.5
- Biochar has a pH of 8; biochar fertilizer can have a pH of 10-12!
- Raising the pH of your soil is the simplest and often most important thing you can do to increase yield





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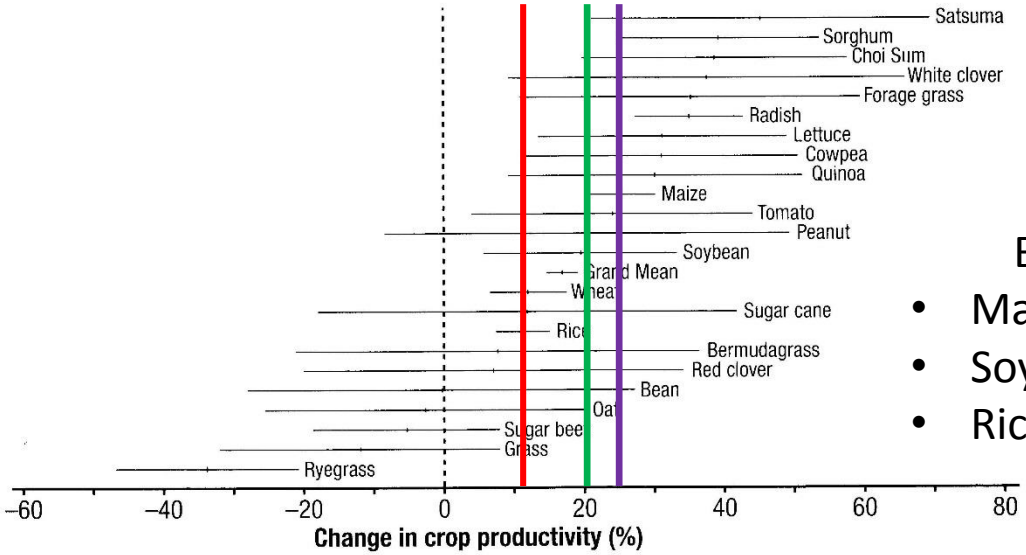
Show me

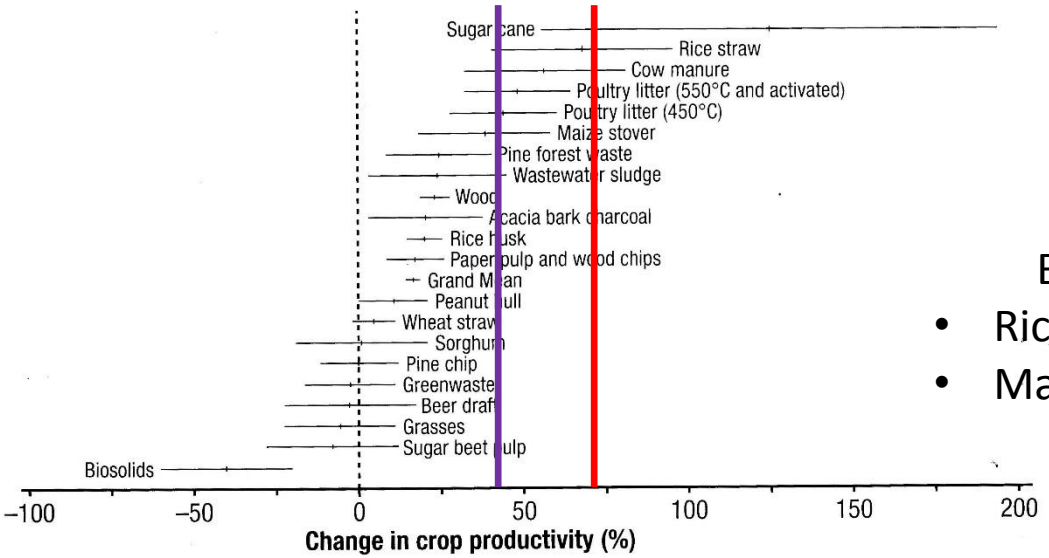
Impact on different crops



Benefit to You

- Maize average 25%
- Soy average 20%
- Rice average 11%

Impact of biochars made from different feed stocks



Benefit to You

- Rice straw 75%
- Maize stover 45%

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Collecting nutrients

- Adding biochar to your soil will make nutrients available to your crops
  - Biochar attracts not only the major nutrients (N, P and K), but also all micronutrients
- Plants cannot take up many nutrients in their elemental forms.
  - The microbes that biochar encourages process the nutrients attached to its surface and make it bioavailable.

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Retaining water

- Adding biochar to your soil can increase your soils ability to hold water
  - Sufficient biochar can increase its ability to support plants for as much as two extra days without rain or watering.

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Fighting disease

- Adding biochar to your soil can help your crops resist a variety of threats
- Exact mechanisms not clear, but include:
  - Activation of microbial communities that control pathogens
  - Activation of plants' own defense systesm
- Biochar has been shown to be effective against:
  - Fungal leaf and root infections
  - Nematodes

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Section IV

How Do You Make Biochar?

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Biochar is complex – but don't panic

- Biochar is so complex that the world's expert on the subject says: "There is no 'biochar'."
- This is true. Biochar varies by:
  - Feed stock used
  - Temperature of pyrolysis
  - Crop it is applied to
  - Soil it is used in
- It is also false. The gross characteristics of biochar seem to be pretty consistent within the range of things ***you*** can control and what ***you*** know.
- Whether in making or using biochar, ***this is the range in which this manual operates.***

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What matters for you

- All pyrolyzers convert biomass into biochar, but biomass comes in two types that require two types of pyrolyzer design
  - Type I feed stocks result from processing that takes place ***away from the field*** and results in large, concentrated piles of biomass at central locations. (Think corn cob, coconut husks.) Type I feed stocks are readily pyrolyzed economically.
  - Type II feed stocks are raw agricultural wastes left scattered ***in the field*** after harvest. Wide distribution and low density make Type II feed stocks difficult to pyrolyze economically. (Think rice straw or corn stalk.)

Our design parameters

Design a practical pyrolyzer for poor farmers throughout the developing world that is:

- Very low cost
- Simple to manufacture and maintain
- Made of readily available materials, preferably from recycling centers
- (Type II) Light weight and portable: all parts light enough for one man to lift; entire unit must fit easily in pickup
- Low labor requirements: must be easily used by two men
- (Type II) Rugged: must take the battering of daily field use and require no bolts, pins or other items that can get lost
- Fast: must be capable of producing 3 loads of biochar daily
- Safe to operate: must not require special safety equipment or pose a burn or fire hazard

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Type I pyrolyzers

Standard TLUD, single barrel, limited capacity, single batch, slow, labor-intensive, often unsafe fire hazard

View of partial Warm Heart ‘Merry-Go-Round’ six barrel TLUD. Barrels tip and rotate for low-effort filling, lighting and emptying. Designed for easy-of-use and safety.

Cost of manufacture – less than $50; plans free from Warm Heart

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Type II pyrolyzers

We know of no readily available in-field pyrolyzers that meet our specs. Warm Heart offers two:

FU2: 3.4 m^3 capacity, Type I or II feed stocks; moved and assembled by 2 men; fits in small pickup with room for quenching water tank and biochar; burn time corn stalk 15 minutes, cob 80 minutes; yield 18%

FU3 prototype: Actual will have 7.7 m^3 capacity, assumed to be Type II only, moved and assembled by 3 men; fits in pickup; anticipated yield, 25%

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Compared by the numbers

	Single TLUD	Merry-Go-Round	FU2	FU3
Volume m^3	0.2	1.2	3.375	7.7
Cob kg	40	240	675	1,540
Stalk kg	N/A	N/A	65	148*
Straw kg	N/A	N/A	128	292
Biochar, cob kg	10.8	64.9	135	385
Biochar stalk kg	N/A	N/A	13	37
Biochar straw kg	N/A	N/A	26	73

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Section V

How Do You Make Biochar Fertilizer?

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Warnings about biochar

- Biochar is great stuff – but it can be dangerous to you and your crops!
  - Keep your biochar wet – the tiny particles can get in your lungs and cause cancer
  - Never – never – put biochar in your soil immediately after making it. ALWAYS age it!
  - Biochar is very powerful – if you use too much you risk:
    - Locking up the nitrogen in your soil
    - Locking up any chemical fertilizers you are using
    - Locking up any pesticides and herbicides you are using

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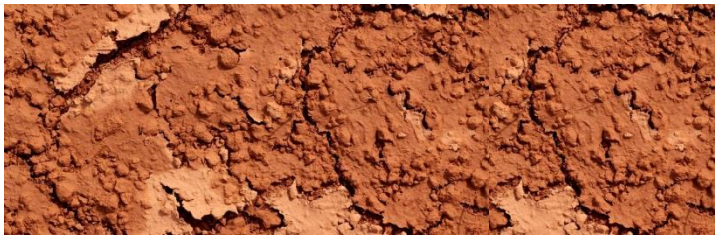
Pre-treatment

- Increase biochar's ability to attract nutrients
  - Sprinkle with rusty water

- Raise the pH
  - Dust with ash – the rusty water will help it stick
- Add trace nutrients and minerals

  - Dust with clay or sprinkle with clay-water mix



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How much do you use?

- No idea
- You are in the world of trial and error
- We use these two rules of thumb:
  - If there are big clouds of black steam when you quench, you probably put on too much ash
  - If there is a lot of grit in the bottom of the quenching barrel, you probably put on too much clay

Post-treatments

- It is very important to prepare your biochar before you put it in your soil so that it can help you in all of the promised ways!
  - Mix your new biochar with rich soil so that it can adsorb nutrients to its surface
  - Mix your new biochar with compost or manure so that it can attract rich colonies of microbes and fungi
  - Spray your new biochar with EM or IMOs to start healthy communities of microbes
  - Mix your new biochar with ash to raise it pH so that it can help to release the nutrients in your soil that your crops cannot use because of the acidity
- And whatever you do – do it for at least 3 months!

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But how do you actually *do* it?

- Easy. Just never forget that gravity is your friend.

- Organize biochar and fertilizer production on a slope with your feed stock at the top and finished fertilizer at the bottom.
- At every step between the two use gravity to make it easier to move the load.
- The diagram on the next slide shows the layout of our farm production facility, but check out this simple tool for mixing the ingredients for fertilizer.

The side door permits this drum to be filled with ingredients and then rolled down hill. It rolls up onto a simple rack which permits it to be emptied straight into bags.

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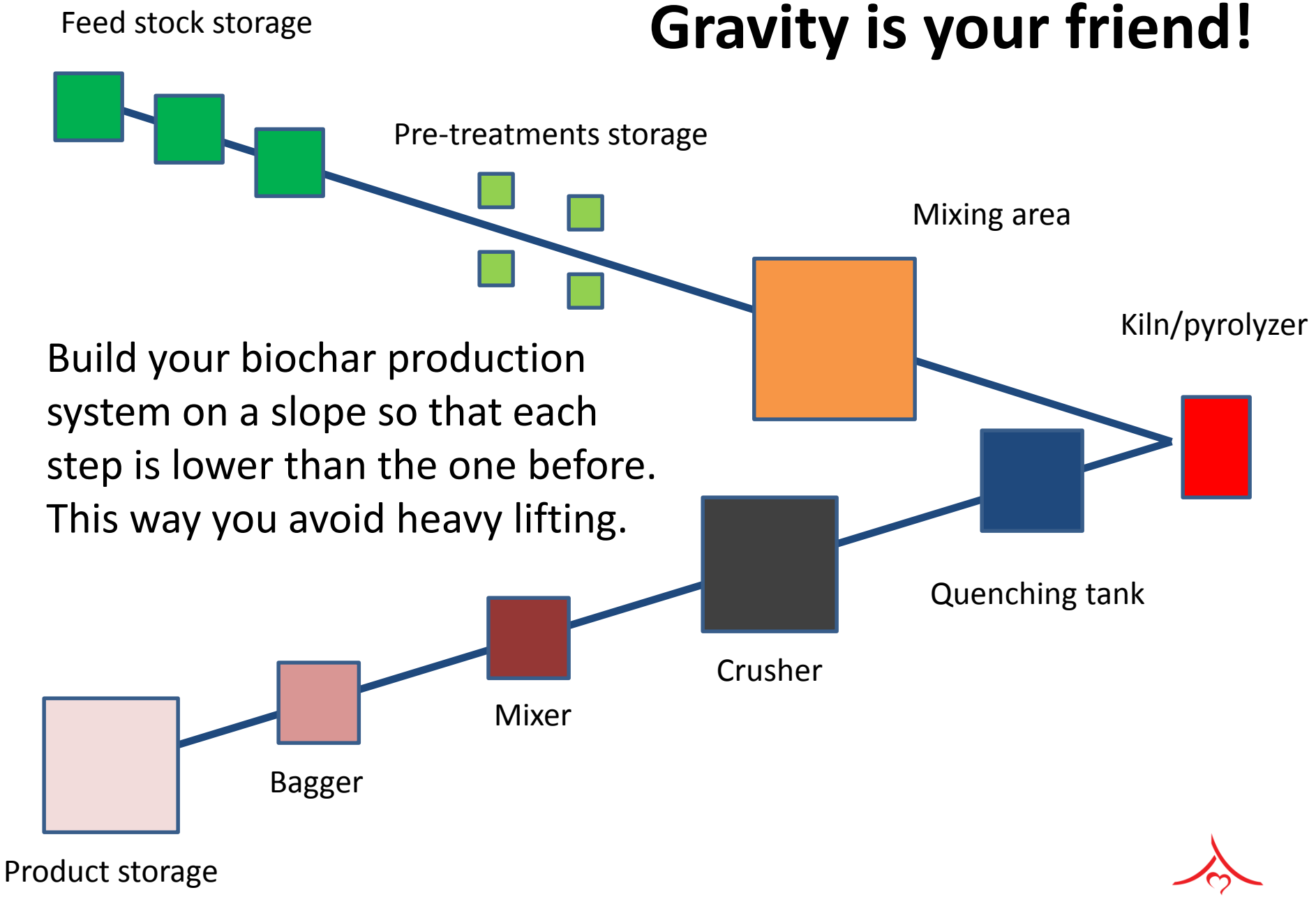
Gravity is your friend!



Build your biochar production system on a slope so that each step is lower than the one before. This way you avoid heavy lifting.

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Remember

- Biochar is ***not*** NPK
  - It will take 3-4 years to achieve its full effect
  - It will ***not*** produce an instant impact
- But it will also ***not***
  - Wash away with the first rain
  - Reduce the fertility of your soil
  - Cost you money every year
- Small amounts of biochar mixed with manure or compost can work better than lots of biochar.
- Small amounts of biochar every year work better than lots of biochar all at once.

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Section VI

What Else Can You Use Biochar For?

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Biochar and chickens

- Biochar has big benefits in poultry raising.
  - Add 1-3% biochar to chicken feed to increase weight gain by 20%
  - Add biochar to chicken and duck feed to reduce disease in a flock
  - Add biochar to the floor litter to reduce the ammonia smell and increase egg production.
  - Add biochar to chicken feed and litter to improve the quality of manure and litter as fertilizer.

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Animal feed

- Biochar improves animal feed.
  - Add 1-3% biochar to cattle and pig feed to increase weight gain by 20%
  - Add biochar to cattle and pig feed to reduce disease in a flock
  - Add biochar to the floor litter to reduce smells and eliminate flies.
  - Add biochar to cattle and pig feed and litter to improve the quality of manure and litter as fertilizer.

Pasture improvement

- Improving pasture can be expensive, but not with biochar.
  - Feed biochar to your cattle feed. (Mix it with a little molasses and they will love it!)
  - The biochar will protect your cattle from many digestion problems and will be improved by the microbes in the cattle's guts.
  - As the cattle graze in the pasture, they manure the fields with high quality fertilizer mix of biochar and manure.

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Water filters

- Adding biochar to your soil can increase your soils ability to hold water
  - Sufficient biochar can increase its ability to support plants for as much as two extra days without rain or watering.
- Biochar in general is highly absorbant, but some biochars absorb better than others
  - High temperature bamboo biochars, for example, and low or medium temperature biochars made from rice straw are very absorbant.

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Bad smells and flies

- Bad smells may be annoying, but flies carry diseases.
- Biochar can help with both.
  - Sprinkle biochar in your outhouse, pig pen, chicken hutch, cow pens and fish ponds.
  - For an even better effect, spray with EM.

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Section VI

Where to Learn More

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Selecting from a wealth of sources

- International Biochar Initiative: ***The*** place to start
  - http://www.biochar-international.org/
- Introductions to key subjects:
  - Biochar in soils
    - http://www.biochar-international.org/biochar/soils
  - Biochar and composting
    - http://www.biochar-international.org/sites/default/files/Compost_biochar_IBI_final.pdf
  - Biochar and climate change
    - http://www.biochar-international.org/biochar/carbon
  - Biochar videos
    - http://www.biochar-international.org/publications/IBI#videos
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