PROAGRO LECTORIUM

Effective Carbon Sequestration Technologies in Ethiopian Agriculture

Solomon Tulu Tadesse
(PhD and Associate Professor)

Jimma University
College of Agriculture and Veterinary Medicine (JUCAVM)

www.ju.edu.et

Presentation Outline

- Introduction
- Effective Carbon Sequestration Technologies
- Carbon Sequestration
- Sustainable land management practices
  - ✓ Organic waste recycling
  - ✓ Organic amendments production and use
    - Biochar (Maize cob, coffee husk)
    - Biochar based composts
    - Bone char (Abyssinian phosphorus)

Jimma University
College of Agriculture and Veterinary Medicine (JUCAVM)

Jimma University: JUCAVM … Background

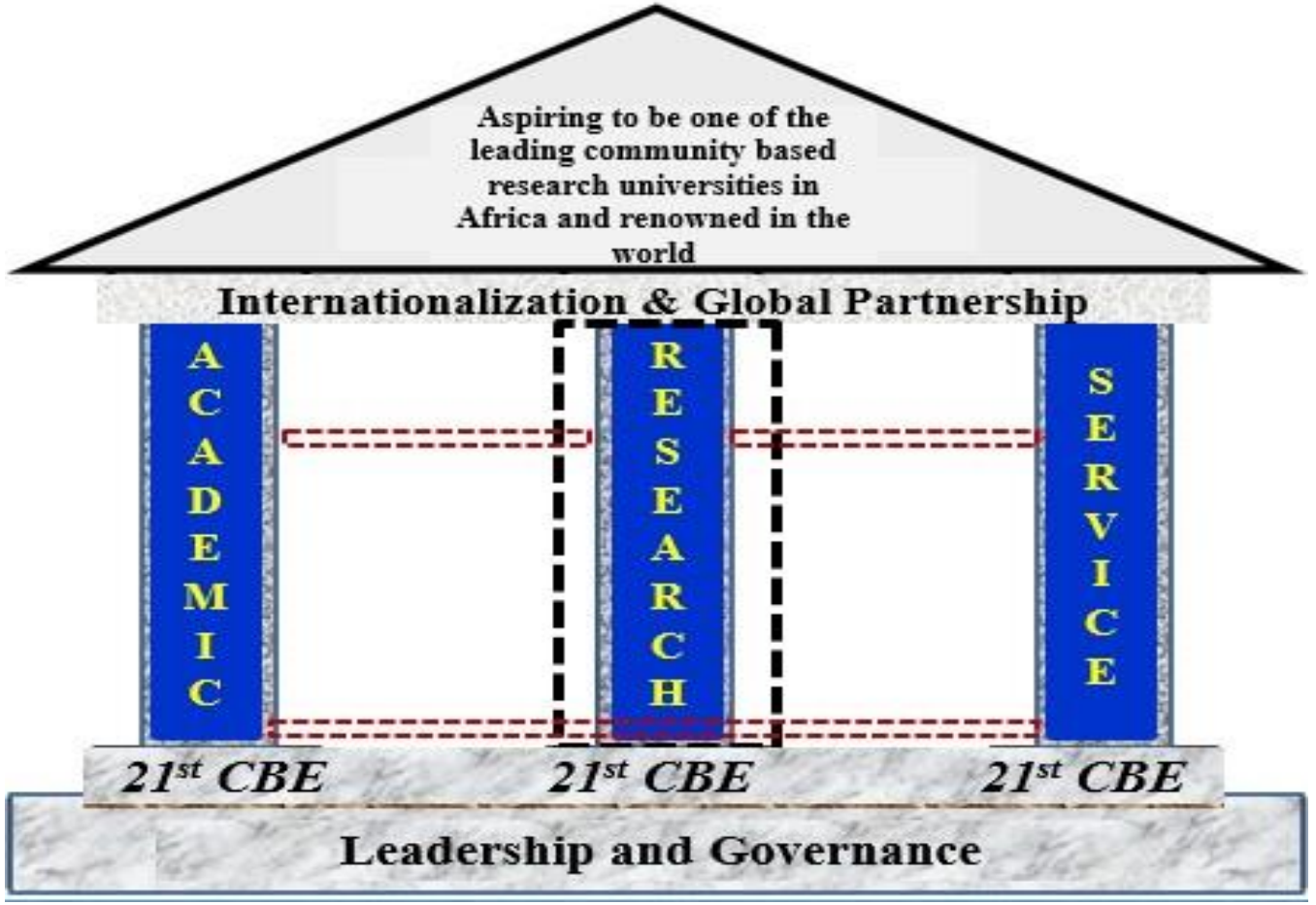
- **Jimma University** was founded in **1999** with the amalgamation:
  - ✓ **Jimma College of Agriculture & Jimma Institute of Health Science,**
  - ✓ **JU** is the first **innovative community-oriented** educational institution & pioneer in public health & agricultural training,
  - ✓ Currently, operating in 4 campuses with 6 colleges and 2 Institutes,
  - ✓ It is one of the **8 research Universities (RU),**
  - ✓ First ranked based on 2013 performance among RU.

Jimma University: JUCAVM … Background

- JUCAVM is established in 1952 as Jimma Agricultural Technical School in collaboration with Oklahoma State University,
  - ✓ Committed to advancing Agri development through training, knowledge generation & service delivery,
  - ✓ It is the first agricultural research station of the country,
  - ✓ one of the oldest & historical schools of Agricultural Education,
  - ✓ It is a foundation of Agricultural Education, Research & Extension.

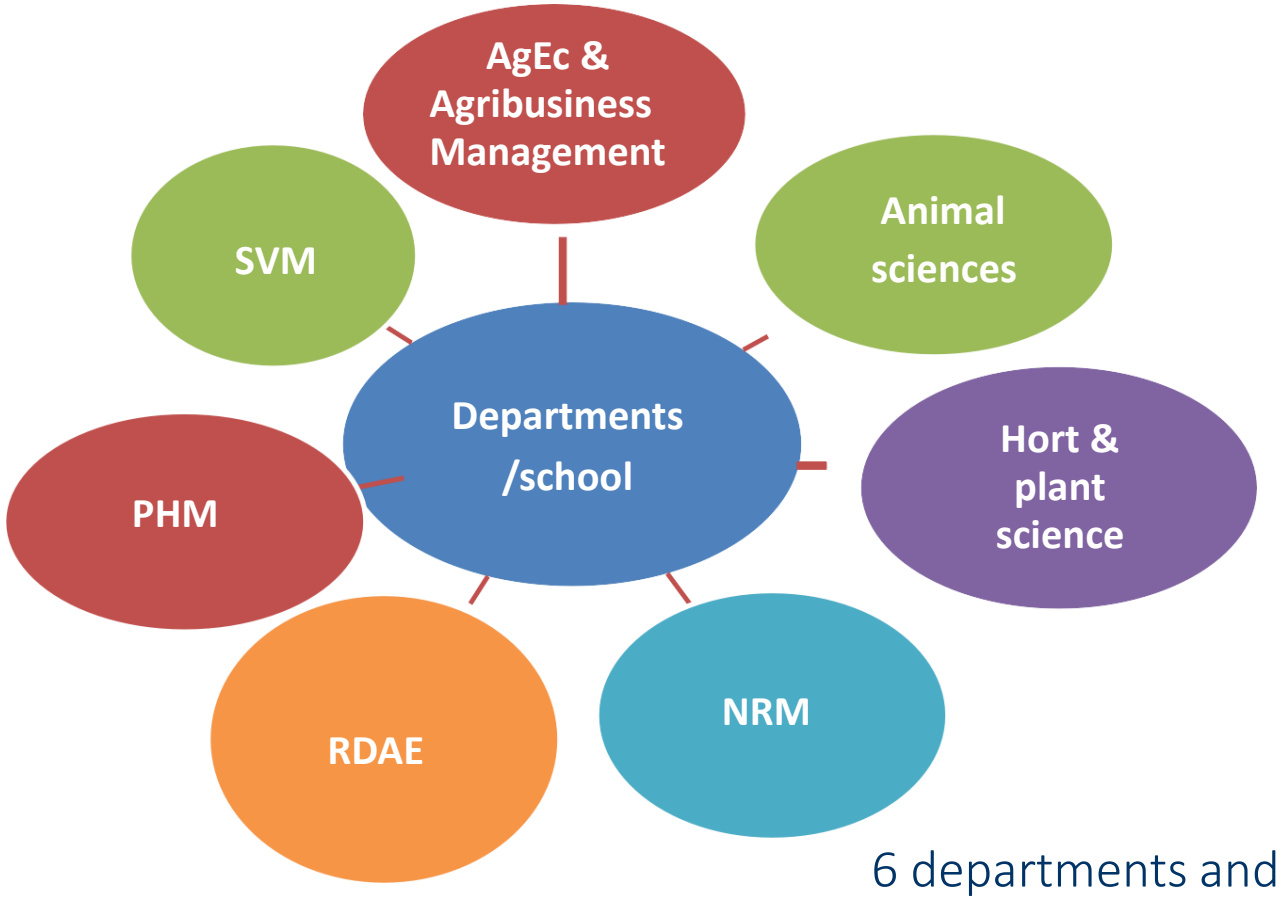
Jimma University: JUCAVM … Background

Vision of JUCAVM



Jimma University: JUCAVM … Background

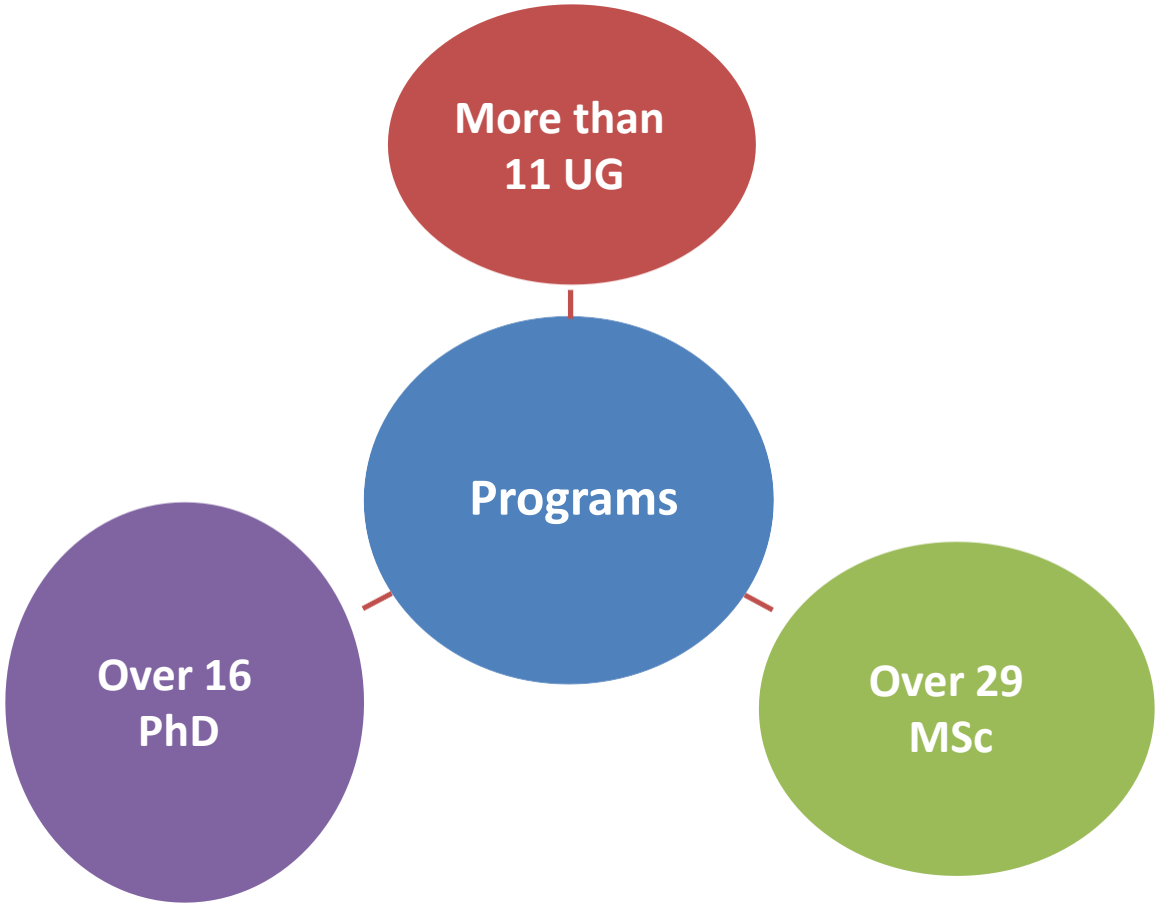
DEPARTMENTS / SCHOOLS



6 departments and one school

Jimma University: JUCAVM … Background

Academic programs



Effective C Sequestration Technologies in Ethiopian Agriculture

- **Carbon sequestration** is transfer of atmospheric CO_2 into other long-lived global pools including oceanic, pedologic, biotic and geological strata to reduce the net rate of increase in atmospheric CO_2, one of the green house gases.
- **Carbon farming** is the use of specific on-farm practices designed to take carbon out of the air and store it in soils and plant material.
- **Carbon farming practices** include application of soil amendments like compost or biochar, conservation tillage, agroforestry, whole orchard recycling, cover crops that maximize living roots.

Effective C Sequestration Technologies …
1. Sustainable land management practices

- Agroforestry and restrained grazing
  - ✓ Had greater stock of soil C compared with traditional management,
  - ✓ Higher C stocks under agroforestry & restrained grazing are explained by higher biomass of perennial vegetation with multilevel canopy & root systems,
  - ✓ Example: Ethiopian Green Legacy.

Effective C Sequestration Technologies …
Afforestation & Reforestation: the Green Legacy

- Ethiopia's Green Legacy is a massive reforestation campaign that was launched by Ethiopian Government in 2019 and done every year.

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GREEN LEGACY

• Afforestation & Reforestation: the Green Legacy …

- Ethiopia's Green Legacy Initiative is a commendable effort towards restoring degraded forests, enhancing ecosystem services (Carbon sequestration & Nutrient recycling),
- Thus, promoting sustainable land-use practices.

Effective C Sequestration Technologies …
2. Organic waste recycling

- Agricultural and urban wastes that make fertilizers, pose great threats to safety & health


Coffee husk


Cow dung


Corn cob


Rise husk


Avocado waste


Animal bone

- These resource can be converted into **biochar and biochar-based fertilizer (BBF),**
- **Biochar & biochar-based fertilizer** from different organic sources are options for improving soil fertility, restoring degraded land & sequester carbon (C).

Manure recycling between UPA & rural farms for OM buildup and C sequestration

- City centers & urban, peri-urban & rural areas are an asymmetrical, uneven & multidimensional continuum,
- No distinct lines separating city center from peri-urban, urban & rural areas but often a slow zone of change exists,
- Accordingly, three zones (A, B, C) were assigned around city centers.

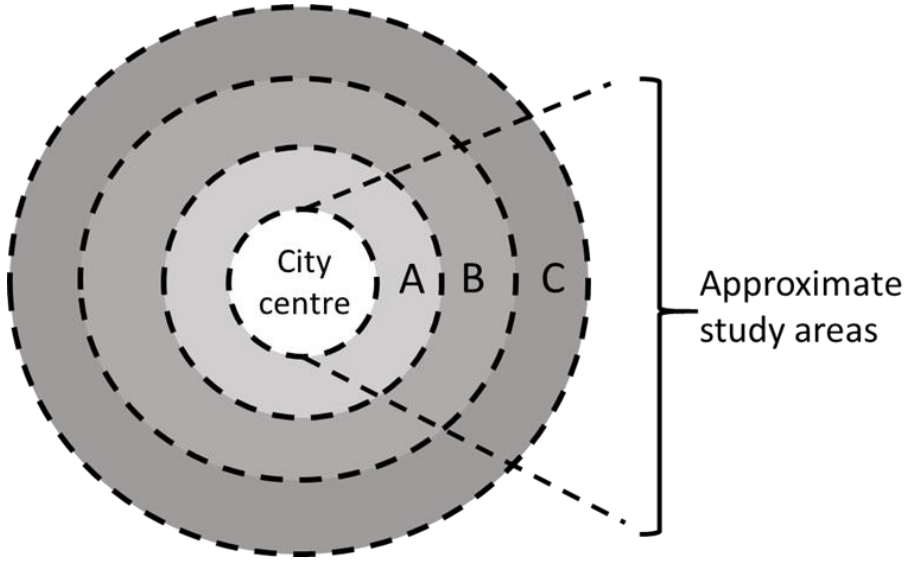


Fig. 1 Conceptual configuration of the studied cities, with a city centre, & an urban zone (A), a peri-urban zone (B) & a rural zone (C) around the city centre.

Manure recycling …

- In each zone type, number & size of farms were identified based on data statistics, & farms survey.

$$Manure\ N, P\ and\ K\ production\ per\ zone\ (kg\ ) = Number\ of\ farms\ per\ zone * average\ TLU\ per\ farm * average\ manure\ N, P, K\ per\ TLU$$

Table 1. Amounts of N, P & K recycled, & cost of synthetic fertilizers saved via manure recycling from urban LS farms to C farms in urban, peri-urban & rural areas of Addis Ababa & Jimma. Ranges show uncertainties in amounts of manure recycled.

City	Manure nutrients recycled, Gg yr^{-1}			Fertilizer equivalents saved, Gg yr^{-1}			Savings, million ETB yr^{-1}
	N	P	K	Urea	DAP	KCl	
Addis Ababa	0.5-2.6	0.2-0.8	0.9-3.7	0.7-3.9	1-4	2.3-9.6	75-300
Jimma	0.04-0.22	0.02-0.07	0.07-0.30	0.1-0.3	0.1-0.4	0.2-0.8	6-24

Note: 1000 Ethiopian Birr (ETB) = 30 US$

Manure recycling …

- Total N, P and K demands were estimated from crop-specific N, P & K demands (kg ha^{-1} $year^{-1}$) per zone, crop type-specific nutrient losses, & surface areas of crops per zone,

Table 2. Number of crop farms and estimated total N, P and K demands by crops grown in the urban (zone A), peri-urban (zone B) and rural areas (zone C) of Addis Ababa and Jimma

Area (Zone)	Addis Ababa				Jimma			
	Number of farms	Total demand, Gg $year^{-1}$			Number of farms	Total demand, Gg $year^{-1}$		
		N	P	K		N	P	K
Urban (A)	1,097	0.11	0.02	0.10	1417	0.11	0.02	0.09
Peri-urban (B)	14,435	3.63	0.52	3.11	1770	0.27	0.04	0.23
Rural (C)	12,199	3.15	0.45	2.70	1018	0.18	0.03	0.15
Total	*27,731*	*6.89*	*0.99*	*5.91*	*4,205*	*0.56*	*0.08*	*0.48*

Manure recycling …

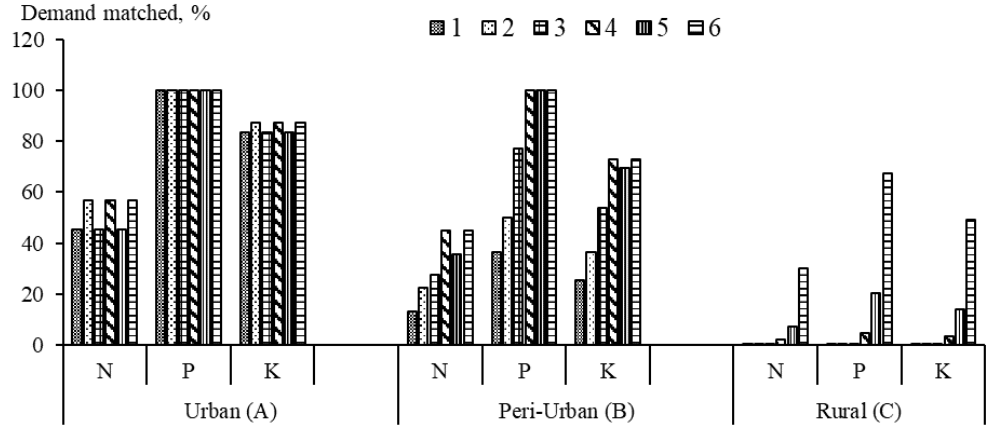


Table 3. Amounts of recyclable N, P, & K in manure in Addis Ababa as function of 6 variants (3 sets of excretion coefficients * 2 sets of recovery fractions)

Cities	Variant	Excretion rates, kg cow^{-1} yr^{-1}			Recovery fraction, %			Recyclable nutrients, Gg yr^{-1}		
		N	P	K	N	P	K	N	P	K
Addis Ababa	1	25	5	25	0.3	0.6	0.5	0.5	0.2	0.9
	2	25	5	25	0.5	0.8	0.7	0.9	0.3	1.2
	3	50	10	50	0.3	0.6	0.5	1.1	0.4	1.8
	4	50	10	50	0.5	0.8	0.7	1.8	0.6	2.5
	5	75	15	75	0.3	0.6	0.5	1.6	0.6	2.6
	6	75	15	75	0.5	0.8	0.7	2.6	0.8	3.7

Gg = gigagram = 1 million kg

Effective C Sequestration Technologies …
3. Soil amendments

- **Carbon sequestration and soil amendments**
  - ✓ Soil amendments are products added to soils to improve soil qualities like soil fertility,
  - ✓ Many of the soil amendments that can improve soil health, also **sequester carbon,** and these includes:
    - Organic matter compost,
    - Biochar (Corn cob, coffee husk),
    - Biochar based fertilizers,
    - Bone char,
    - Abyssinian fertilizer.

Organic matter compost use for crop production

- Manure accumulation recyclable to urban and rural farms as organic amendments for C sequestration.
  - ✓ Conventional compost production.

Organic matter compost use cont. …

- Manure & crop residue stored in rural areas for animal feed & manure collection for fertilizing farms for food and feed production that leads to C sequestration.
  - ✓ Conventional compost production.

What is Biochar?

- Biochar is a carbon-rich solid material produced by heating biomass in an oxygen-limited environment.

Effects of biochar

Positive effect

- Sequester stable Carbon
- Increase CEC, retain nutrients,
- Modifies biological properties
- Reduces soil acidity
- Improves plant growth and enhances crop yields
- Reduction of heavy metals (Pb, Cd) bioavailability

Biochar Production

Kon-Tiki Kiln

A Low Cost Low Emissions Kiln for Producing Low and High temperature Biochar Mineral Complexes

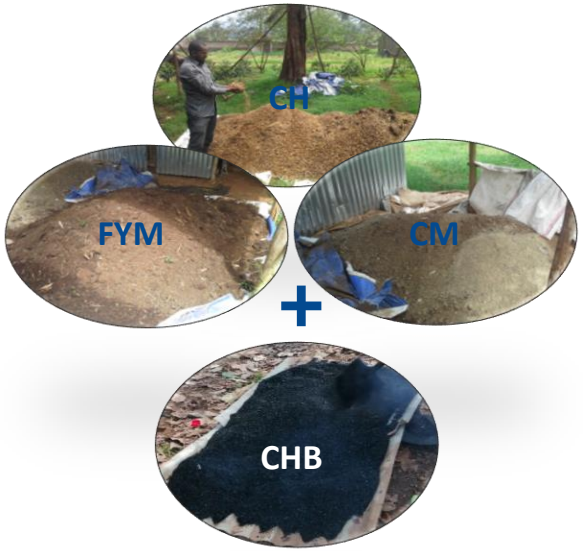
- Can be made cheaply and can produce a range of different biochar
- Above and in ground units
- Easy to fill, start, operate, quench and unload





Biochar Application

- Biochar can be directly applied to soil or
- Can be combined with other forms of waste and produce indigenous fertilizers in their back yard



Biochar based fertilizer

Biochar production and use






Biochar based fertilizer production

3:1:1 ratio (by volume) and composted

Conventional Compost

+

Biochar 20% of the total mixture mixed & co-composted

Biochar based fertilizer

+

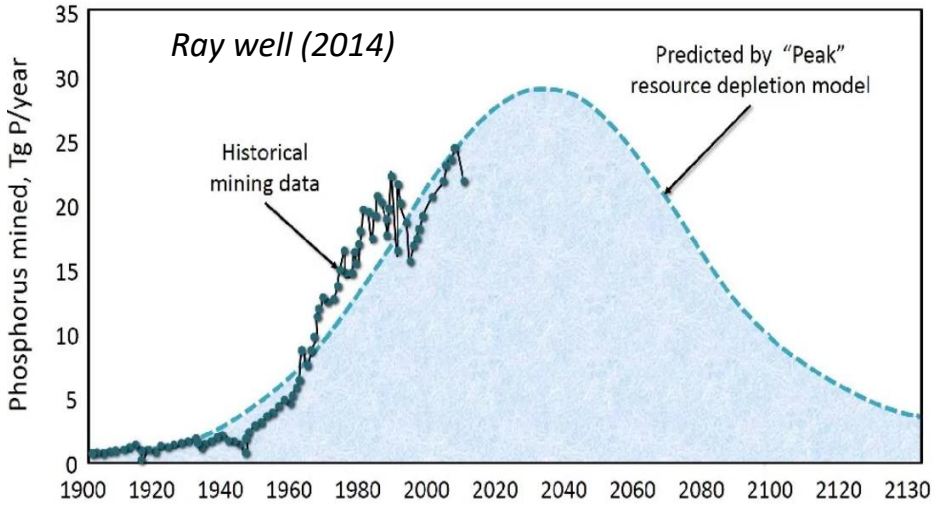
Biochar 20% & bone char mixed & co-composted

Biochar based fertilizer + bone char

Bone char: sustainable & indigenous P-fertilizer & food security

Global Phosphorus Supply and Scarcity

- P demand - estimated to increase 51–86% by 2050 (Mogollon et al. 2018).
- P is a nonrenewable resource with a finite supply.
- Most (73–76%) are mined in China, Morocco, or United States.



This scarcity raises two concerns

1. **Geopolitical issues that can cause high prices & volatility**
   - 135% export tariff on rock phosphate
   - 800% spike in prices
   - Food crises in 47 countries

2. **Mineable rock phosphate, can be depleted**
   - The life span of remaining rock P (between **70 and 250 years)**

- More certain is that as reserves decrease & demand grows, prices will increase

Options to Mitigate Phosphorus Scarcity

- An alternative & renewable solution to reduce the dependency on RP


Animal bone


Sewage sludge


Plant biomass

Animal bone - huge potential to secure the demand especially in developing countries.

~100 million animals from 2008 - 2011 in Ethiopia (Simons et al. 2014)

Table 1 | Total phosphorus in annual bone residues from slaughtered animals in Ethiopia.

	Total no. of animals[5]	Bone mass[6] (kg per animal)	% of animals slaughtered (per year)	Bone residues (tonnes per year)	Total phosphorus (tonnes per year)
Cattle	50,283,000	20–30	16–17	160,908–256,447	-
Sheep	23,642,000	4–5	19–34	17,968–40,192	-
Goats	22,070,000	4–5	15–30	13,242–33,106	-
TOTAL	95,995,000	-	-	192,118–329,744	17,279–36,272

Averages of total phosphorus from 2008–2011; average phosphorus concentration in bones of 9–11% (taken from ref. 8).

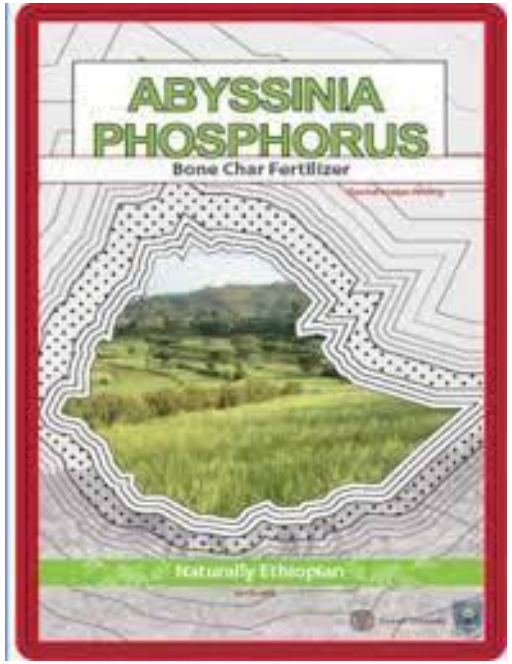
28-56 % of annual P

Field experiments for testing the product

- Biochar and bone char based indigenous fertilizers more than double the farmer yield in on farm trial

Abyssinian Fertilizer

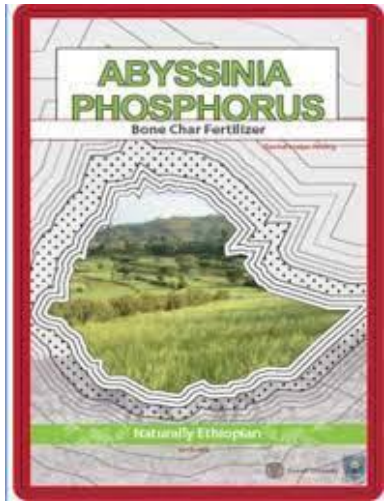
Developing phosphorus fertilizer from bone waste through pyrolysis: Success stories, challenges, and opportunities in Ethiopia



ACP-EU Cooperation Program in Science and Technology II
G.C. FED/2013/330-236
A program of the ACP Group of States, with the financial assistance of the European Union

Pyrolysis

Packaging



Demonstration

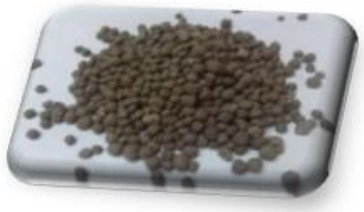
Illustration on the production of Abyssinian phosphorus fertilizer

Grinding unit

Pyrolysis

Mixing and binding unit

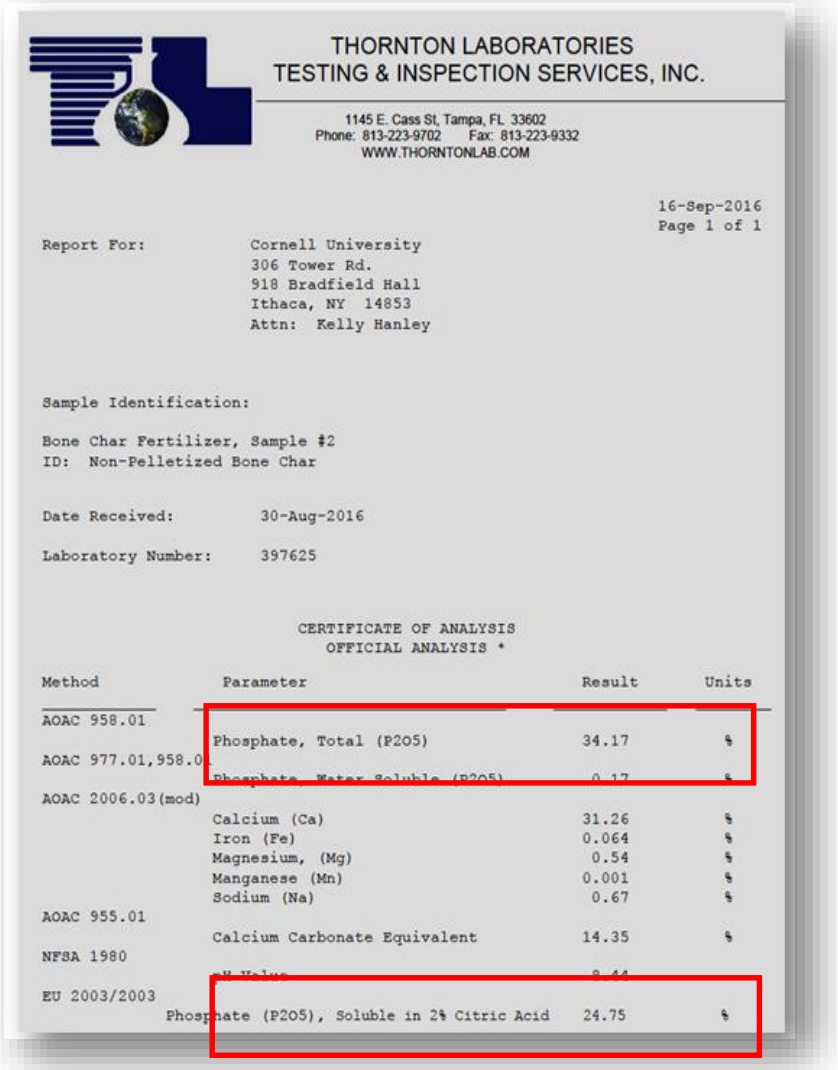
Pelletizing unit



Triple super phosphate (TSP)

Goal is to develop an Indigenous P fertilizer in Ethiopia similar in it form and also with 70% equivalency in available soluble phosphorus content to that of the most expensive commercial fertilizer which is TSP

Chemical composition of the Abyssinia P fertilizer



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16-Sep-2016
Page 1 of 1

Report For: Cornell University
306 Tower Rd.
918 Bradfield Hall
Ithaca, NY 14853
Attn: Kelly Hanley

Sample Identification:

Bone Char Fertilizer, Sample #2
ID: Non-Pelletized Bone Char

Date Received: 30-Aug-2016

Laboratory Number: 397625

CERTIFICATE OF ANALYSIS
OFFICIAL ANALYSIS *

Method	Parameter	Result	Units
AOAC 958.01	Phosphate, Total (P2O5)	34.17	%
AOAC 977.01,958.0	Phosphate, Water Soluble (P2O5)	0.17	%
AOAC 2006.03(mod)	Calcium (Ca)	31.26	%
	Iron (Fe)	0.064	%
	Magnesium, (Mg)	0.54	%
	Manganese (Mn)	0.001	%
	Sodium (Na)	0.67	%
AOAC 955.01	Calcium Carbonate Equivalent	14.35	%
NFSA 1980	pH Value	8.44	
EU 2003/2003	Phosphate (P2O5), Soluble in 2% Citric Acid	24.75	%

[Ethiopia Looks to Animal Bones to Ensure Food Security (triplepundit.com)]

[Can Mountains of Animal Bones Boost Food Security in Ethiopia? · Global Voices]

Cost of bone char P production vs imported mineral fertilizer

Cost comparison bone char fertilizer versus imported alternatives.

	Low Est.	High Est.
Farmgate Price per 100 kg of bone char fertilizer	USD 27.05	USD 37.10
Farmgate Price per 100 kg of triple super phosphate (TSP) equiv.[a]	USD 39.49	USD 54.16
Farmgate Price per 100 kg of imported TSP[b]	USD 64.49	USD 64.49
Farmgate Price per 100 kg of diammonium phosphate (DAP) equiv.[c]	USD 56.80	USD 71.48
Farmgate Price per 100 kg of imported DAP[d]	USD 75.00	USD 75.00

Source: Simons et al., 2023; Food policy

Cereal & leguminous crop trials using Abyssinia phosphorus

- Multi-year agronomic trials since 2012
- *~ 20 farmers field trial at Jimma*
- *50 farmers at Sidama*
- *> 15 pot trials*

Amount of bone produced at Addis Ababa, Jimma, Adama and Hawassa

- From four major cities: 35,000 Mt – 100,000 Mt/ year
- National production is estimated as: 300,000 Mt/ year

Amount of phosphorus found in discarded bone in four major cities

- From four major cities: 4,000 Mt – 10,000 Mt P/ year
- National P production from bone is estimated as: 30,000 Mt P/year

Amount in foreign currency saved – four major cities

- From the four major cities: 30 – 102 million $
- National production is estimated as: 300 million $

Conclusions

- The use soil amendments that can improve soil health, also **sequester carbon.**
- However there is low level of recycling (circularity), and **carbon sequestration.**
- Lack of knowledge, advisory services, & policy incentives & cultural & institutional barriers prevent organic wastes recycling and thus **carbon sequestration.**

Recommendations

- Policy makers should prioritize & define research & policies related to:
  - ✓ Use soil amendments that can improve soil health and **carbon sequestration.**
  - ✓ The recycling (circularity) organic wastes and **carbon sequestration.**
  - ✓ Awareness creation, advisory services, policy incentives, to reduce cultural & institutional barriers, which prevent organic wastes recycling & thus **carbon sequestration.**

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