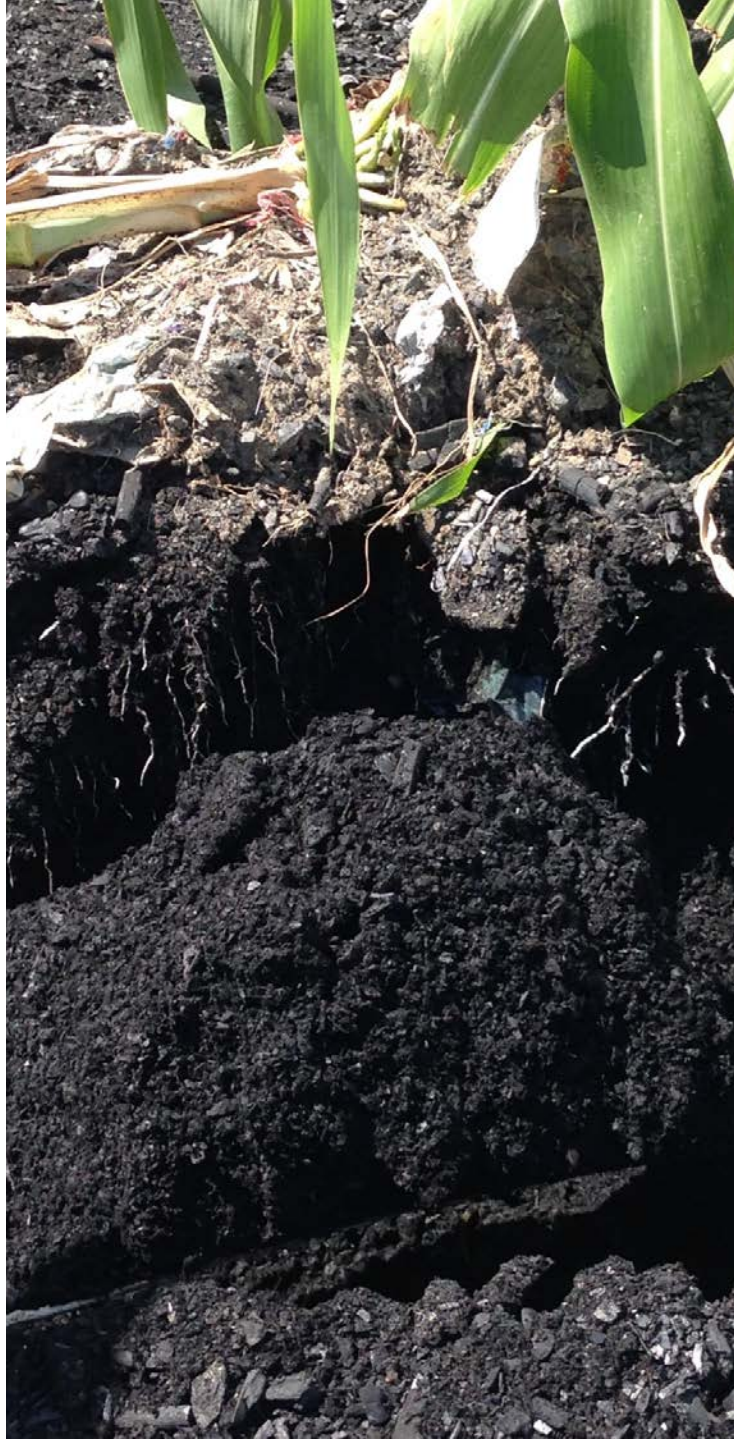


Biochar for Soil Restoration and Environmental Management:

An Integrated Food-Energy Systems (IFES) Approach

Roy Beckford, Ph.D.

ECHO International Conference, November 2016

Haiti: Stolen Ecology

- About 10% of Haiti's soils remain – most eroded
- Approximately 1% of natural forest cover remains
- Named one of the countries least able to rebound from natural disasters (*UNDP*)
- Most at risk from climate change (*Climate Change Vulnerability Index*)

Columbus to *La Isabella*

Columbus's contact with the lands across the Atlantic Ocean was considered a significant maritime achievement resulting in unprecedented wealth acquisition by the dominant European nations at the time. It spelled genocide to the native people of the Americas.

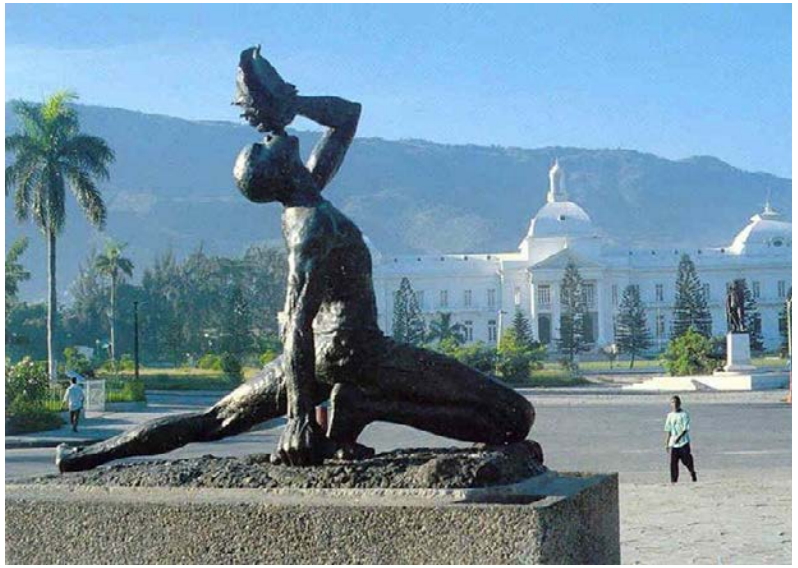
La Isabella to *pearl of the French West Indies*

- After being ceded to France from Spain in 1695, the colony of Haiti grew into economic significance as a result of France's reliance on heavy importation of African slaves*
- This stimulated and boosted agricultural production based mainly on forestry, coffee, and sugar-related industries.

From *Pearl* to *Pariah (St. Domingue to Ayiti)*

- The Haitian Revolution (1791–1804) culminated in the elimination of slavery

"Nothing would be easier than to supply everything for your army and navy, and to starve out Toussaint," **Thomas Jefferson** to **Louis Andre Pichon.**



The Negro Maroon – Spirit of Haiti

Haiti: *From Financial Colonialism to Disaster Capitalism*

Haiti's poverty has forced its people to remain dependent on forest-derived charcoal for cooking fuel, and increasingly, this has accelerated the destruction of the territory's last remaining forested areas.

- 37.4 million cubic meters of wood biomass (30,000,000 trees) removed for fuel each year.
- Replanting rate of 20 million trees with 40% survival rate.
- 3 trees per person removed per year at replanting rate of 2, and survival rate of less than 1 tree per person.

Haiti: The Contemporary Reality

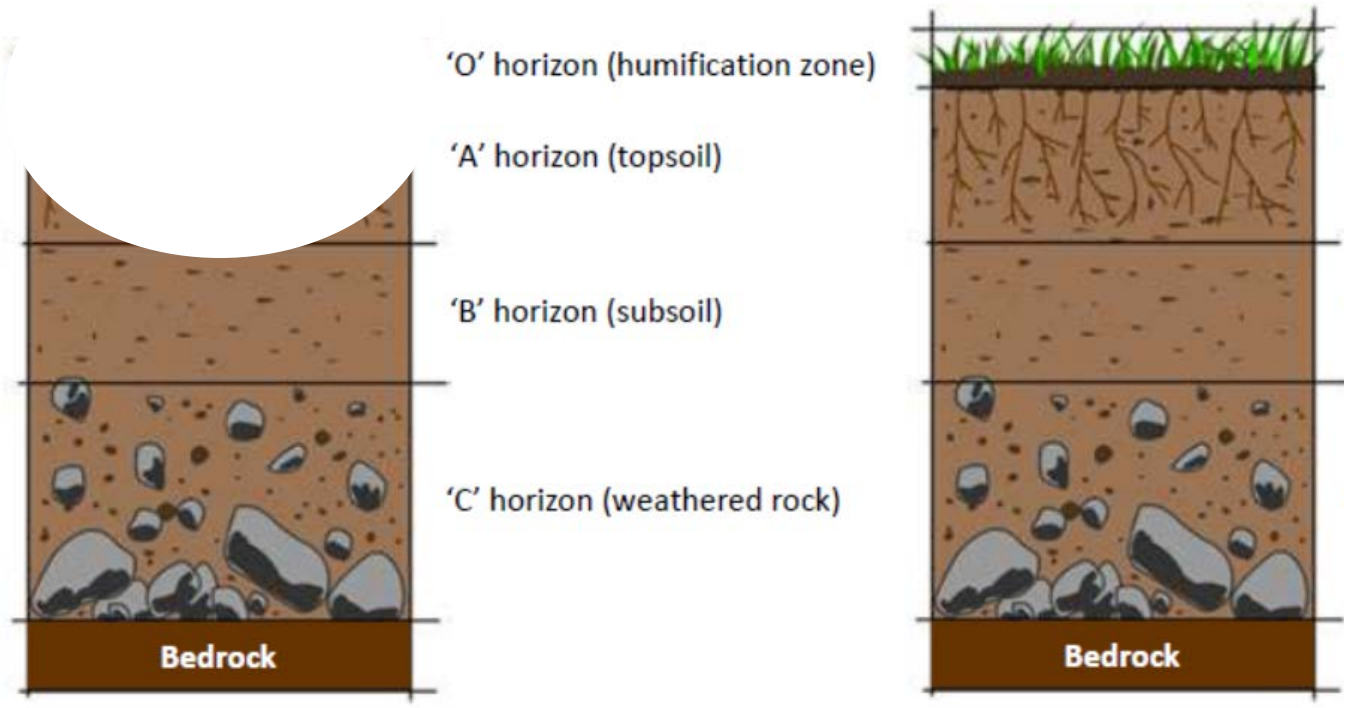
- Of Haiti's 10.2 million people, 80% live below the poverty line
- 54% live in extreme poverty
- 60% of the food consumed by Haitians is imported
- Subsistence farming is the main source of income for 70% of working population
- 80% of domestic energy derived from fuelwood and charcoal
- Charcoal is used by 90% of households in the capital city of Port-au-Prince

Haiti: Broken Environment

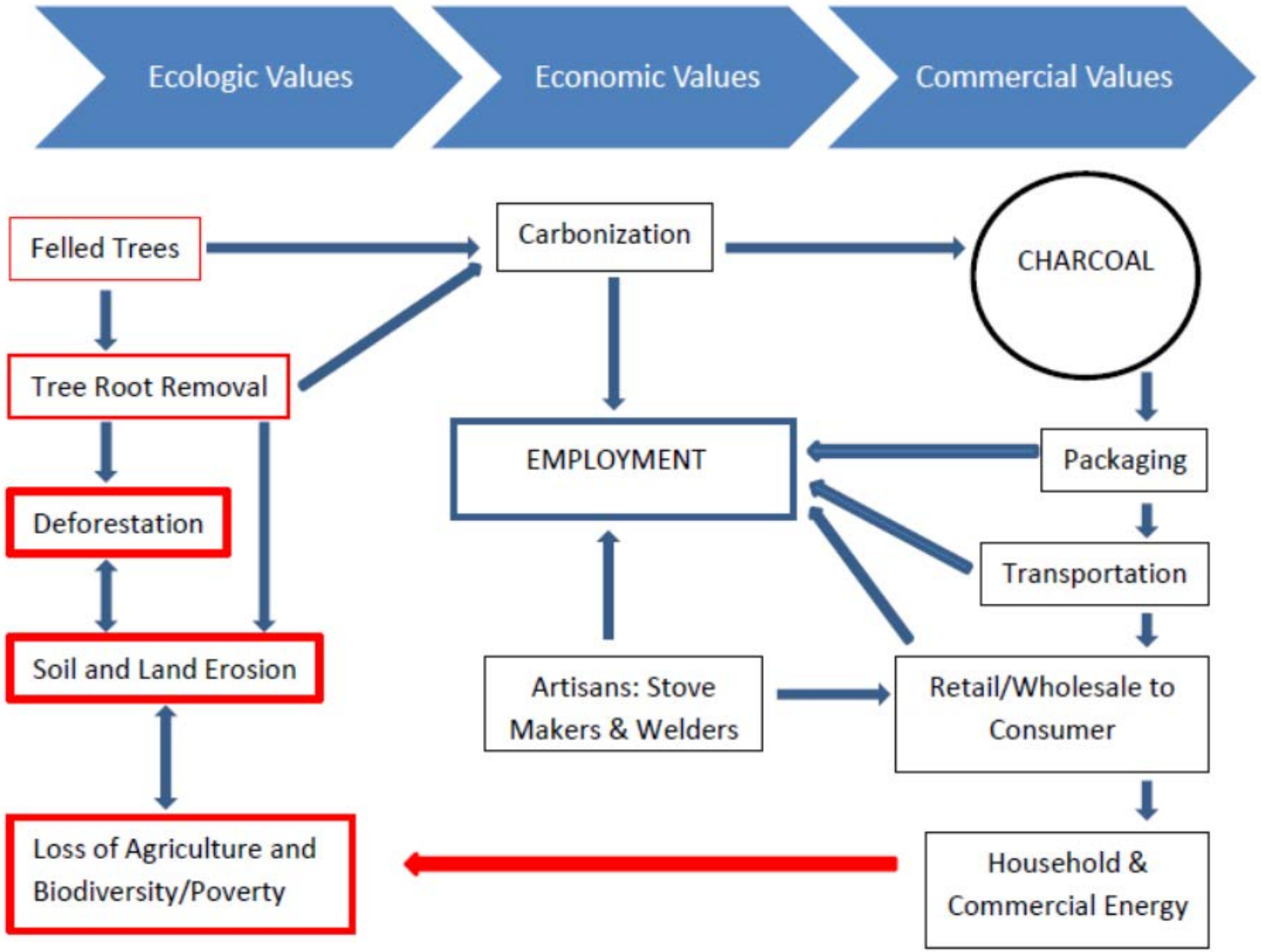
Buried Soils Discovery

Haiti's Soil Horizons

- More than 60% of Haiti's soils are deeply eroded down to the B horizon, and 20% to the C horizon (*Paskett & Philoctete,1990*).



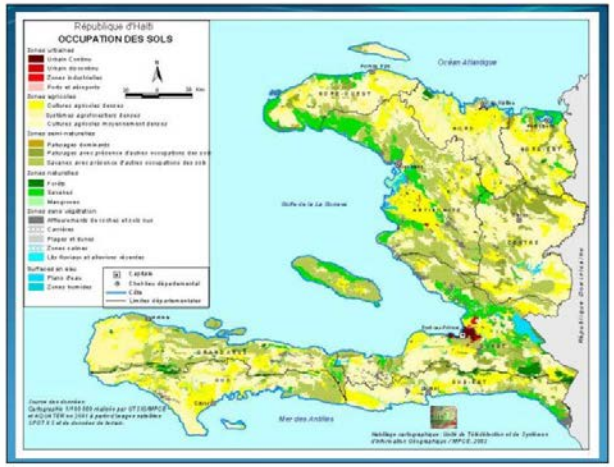
The Charcoal Consumption Chain



Perception and Blame?

Failing Haiti:

How Blame, Disasters and Foreign Aid Have Destroyed the Haitian Environment



Kona L. Shen
Development Studies
Brown University
April 11, 2010

Thesis submitted in partial fulfillment for the degree of BACHELOR OF ARTS in DEVELOPMENT STUDIES

Research Questions/Research Methods

1. What are the dominant ideological biases that have constrained Haiti's social-economic progress over time, and what mechanisms ensured their perpetuation?

2. To what extent are historical, ecological, and scientific factors contributive to Haiti's current environmental problems?

3. Will an Integrated Food Energy System (IFES) model aid the restoration of ecosystems services in ecologically degraded environments, and how can the model be demonstrated in the Haitian context?

Critical Theory

New ways of interpreting the past

Participatory Action Research

Seeks to understand the world by trying to change it, collaboratively

Applied Research

Applies scientific method to examine intervention in real world

Cause and Consequence Correlation

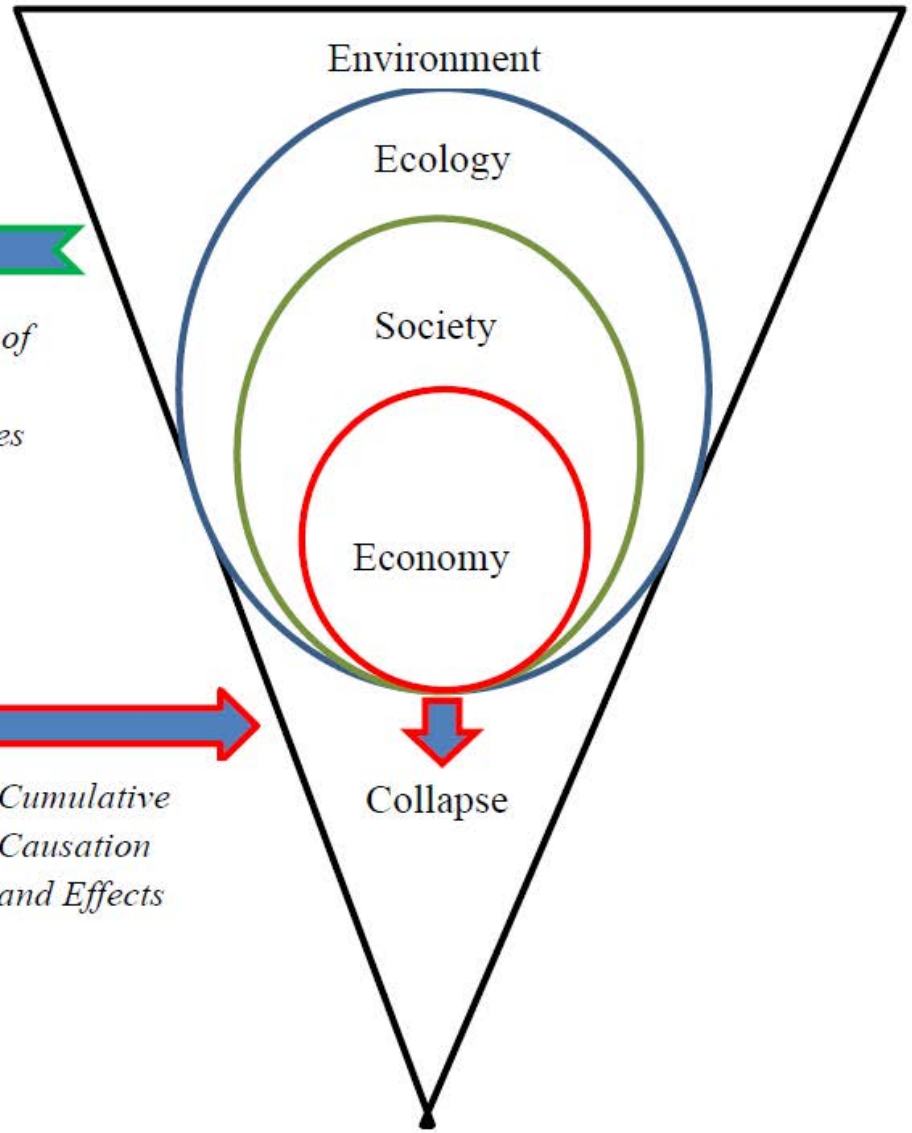
Political Ecology

- **Colonized State: 1492-1803)**
  - Columbian Exchange
  - Exotic Invasive Species
  - Mercantilism and Slavery
  - Agriculture and Logging
  - Environmental Decline
- **Pariah State: 1804-1914)**
  - Diplomatic Boycott
  - Trade Embargo
  - Financial Reparation
  - Extensive Logging
- **Occupied State: 1915-1949**
  - Neocolonialism and Taxation
  - Mining and Logging
  - Land and Soil Erosion
  - Economic Malaise
- **Fragile State:1950-1986**
  - Population Explosion
  - Biodiversity Loss
  - Agricultural Decline
  - Peak Deforestation
  - Ecological Tipping Point
- **Welfare State: 1987-2015**
  - Desertification
  - Peak Soil
  - Peak Charcoal
  - Ecological Collapse
  - Agricultural Collapse
  - Energy and Food Poverty
  - Absolute Poverty

Outflow of Natural Resources

Cumulative Causation and Effects

Ecological Economy



Re-diagnosis and Reassessment

- **The root of Haiti's modern environmental and social crises lies in the damage done to its biogeochemical cycles, the most significant of which is destabilization of the carbon cycle.**

Biophysical Factors	+	Anthropogenic Factors	=	Carbon Loss
➢ Topography ➢ Soil Type ➢ Bimodal Rainfall		➢ Historical Deforestation ➢ Agricultural Practices ➢ Charcoal Production		➢ Runaway Soil Erosion ➢ Loss of NPP

- Runaway soil erosion represents the largest source of loss to the carbon cycle
- This problem affects NPP and exerts the greatest effect on the delivery of ecosystem services necessary for economic activity

IFES Research Approaches

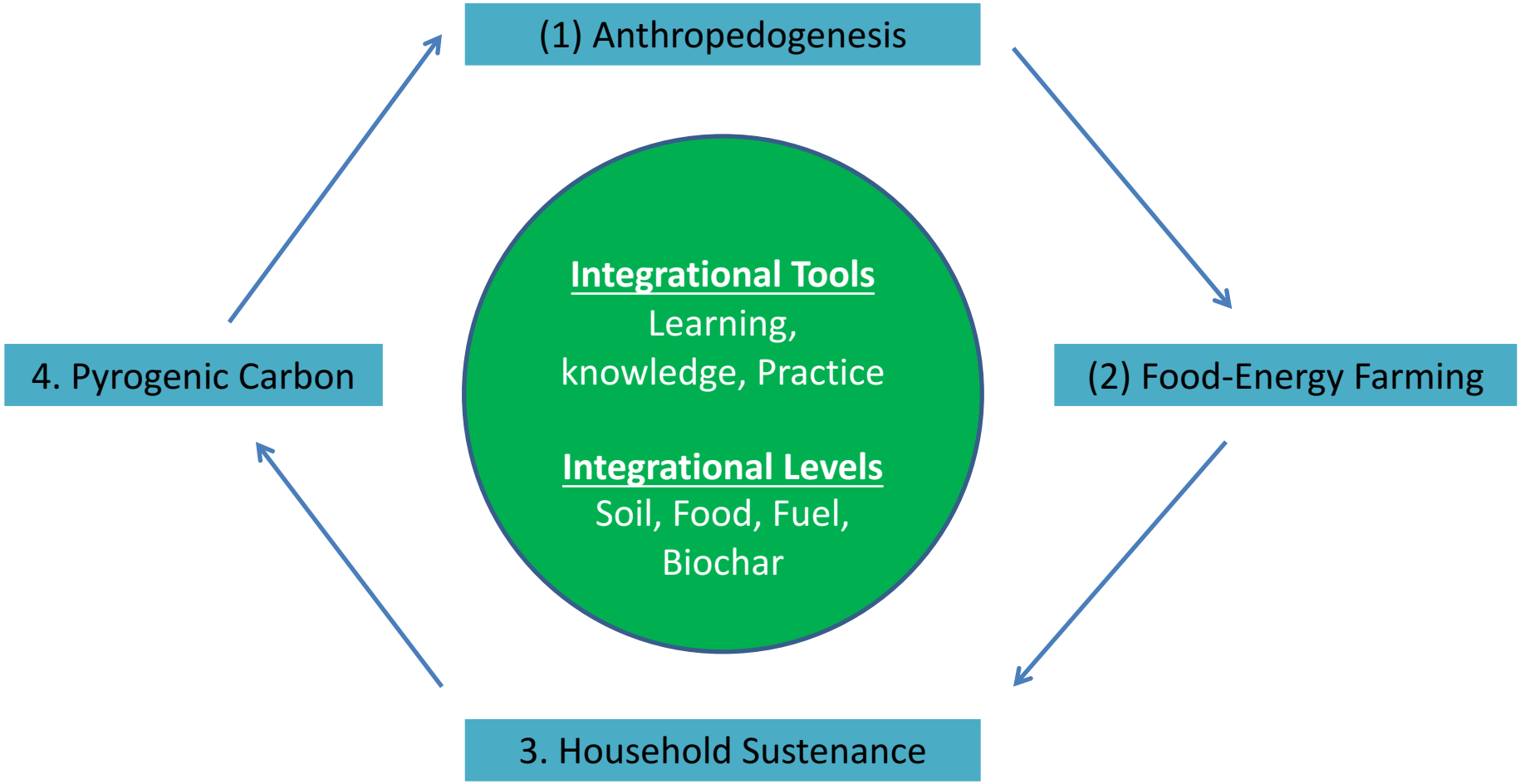
1. Restorative anthropedogenesis: A Proxy evaluation in Florida
2. A survey of farmers across Haiti
3. An assessment of farmer perceptions of Haiti's food-energy ecology
4. Restorative anthropedogenesis: In-situ experiment in Haiti
5. Evaluation of clean cookstove for biochar production from sustainable farm grown energy biomass

Integrated Food Energy System?

- An *integrated food energy system* (IFES) *response* as a ‘systems approach’ to development in which there is the application of resilience strategy encompassing soil, environment, technology, food and energy, in a synergistic relationship with existing biophysical, socio-economic, and political interdependencies.

- An IFES integrates, intensifies, and consequently aims to increase the production of food and energy per unit of land by transforming the by-products of one system into the feedstocks for the other.

Components of IFES, contextualized to Haiti



Proxy Evaluation in Florida

- Evaluating ***compost-only*** versus ***compost-biochar*** applications on sandy soil horizon

i. Two inch coat of compost atop sandy soil.

ii. 101.22 pounds of biochar was required for each treated subplot.

iii. Conuco mounds constructed

Making Biochar
(for anthropedogenesis)

Air flow control at barrel base

Hole to allow air updraft

Biomass (Palm Fronds)

Making Biochar
(for anthropedogenesis)

TLUD pyrolysis in action

Dousing the glowing char

Finished, cooled biochar

Biochar is made by heating biomass under the exclusion of air. This process is called pyrolysis, which includes the drying of the biomass and the subsequent release of flammable vapors.

What is biochar?

- Biochar can be broadly characterized as “thermally-modified biomass”, but it is NOT charcoal
- Biochar is carbon-rich, containing significant fractions of amorphous graphitic domains (as in “tiny pockets”) and additional organic carbon properties.
- The graphitic domains within biochar have been documented to be stable in the soil for millennia, including samples isolated from historic Terra Preta sites.

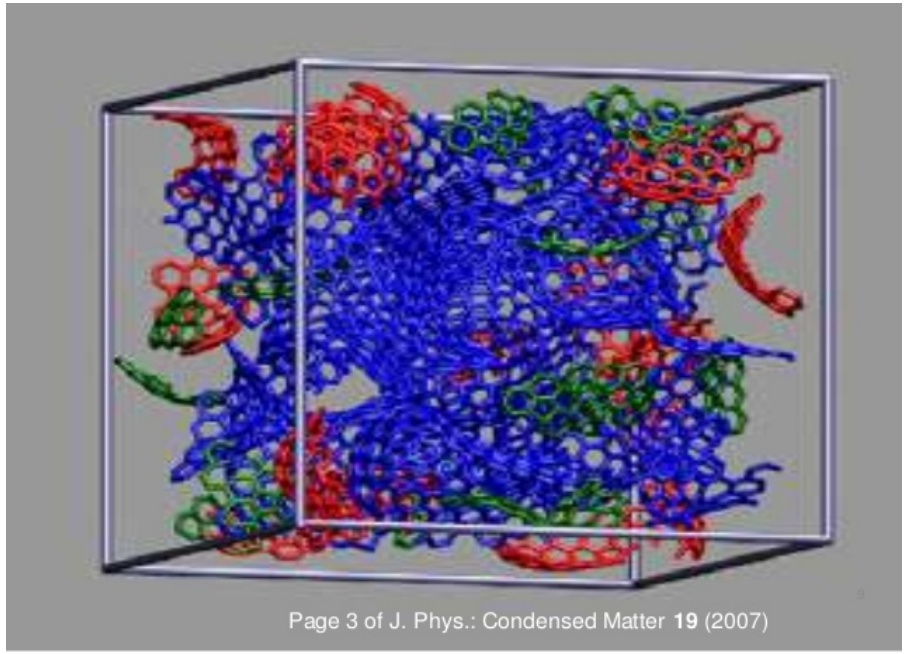


Figure 4: Development of porous 3-dimension structure during carbonization

What is biochar?

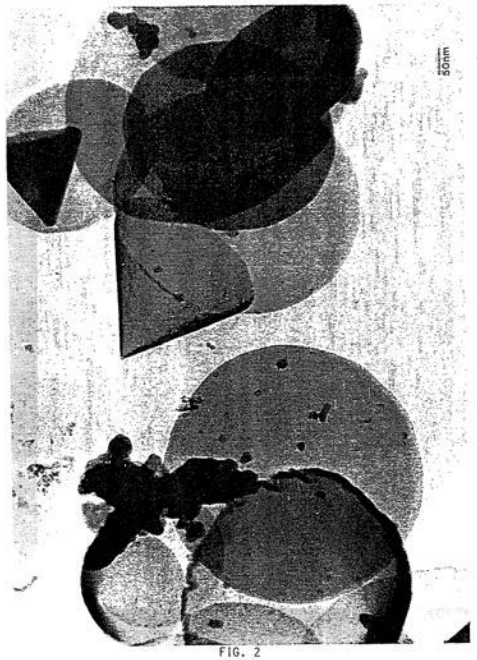
- Biochar also has properties and molecular structures that resemble activated carbon, a common industrial material that possesses unique adsorption properties for vapor and liquid phase organic molecules.
- The thermal modification of biomass is significant because it results in a pivotal property of biochar – the ability to persist in the soil by not being susceptible to biological decay.
- Persistence basically makes biochar a soil “catalyst”, in the sense of facilitating reactions beneficial to the soil dynamics

How is biochar created?

- The specific thermal modification that converts biomass into biochar can be viewed from two closely related perspectives called “pyrolysis” and “carbonization”.
- The pyrolysis perspective focuses on the chemical breakdowns that result in the liberation of pyrolytic gases.
- The carbonization perspective focuses on the chemical build-ups of the carbon atoms into solid structures.
- The bulk of pyrolysis and carbonization reactions occur in the temperature range **from about 200 to 500 degrees C**.
- One can think of pyrolysis and carbonization as simultaneous physical-chemical processes, changing the biomass into pyrolytic gases and charcoal.

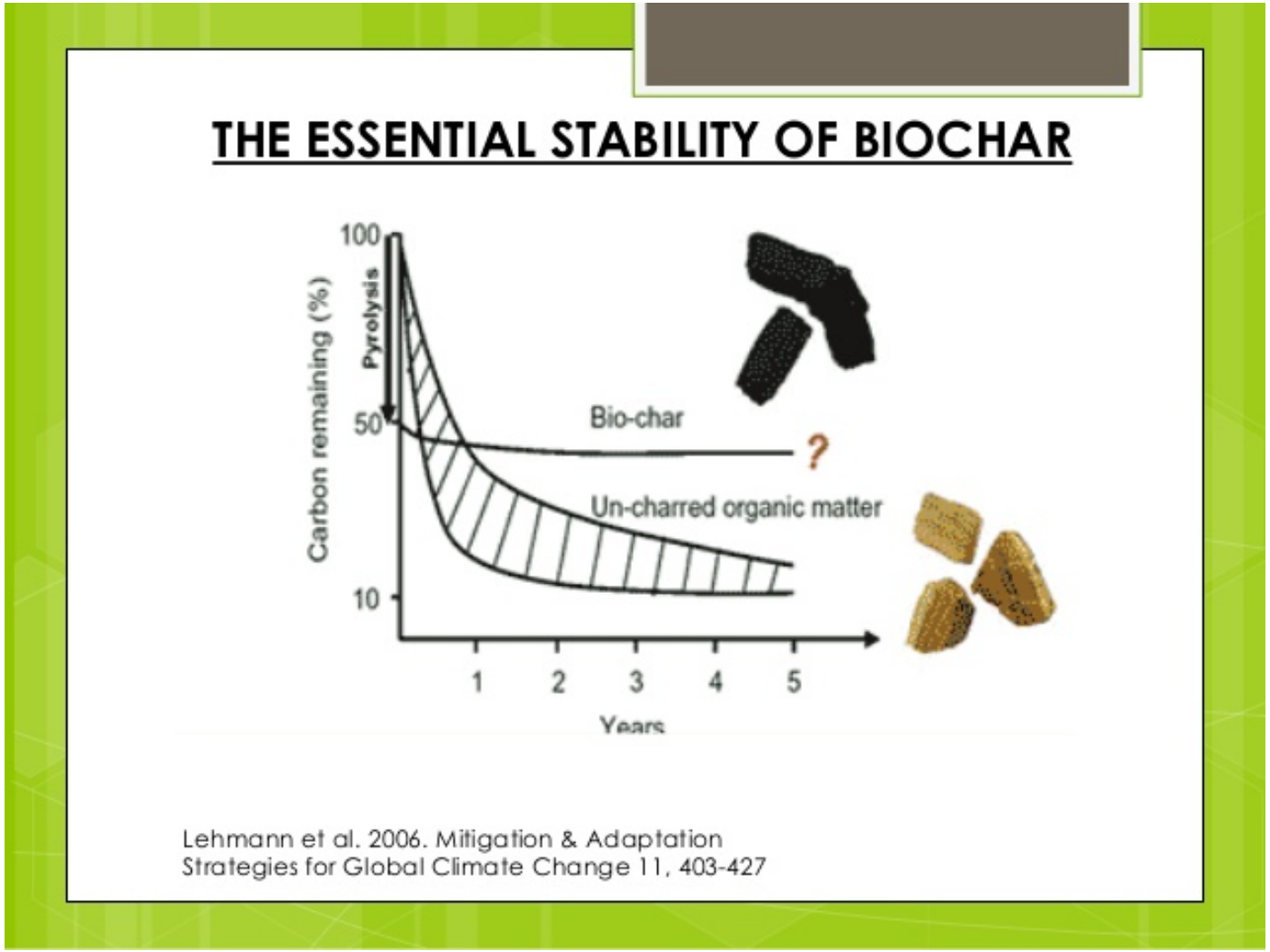
How is biochar created?

- At sufficient temperatures, generally above 300 degrees C, carbonization modifies the chemical bonds within the remaining solid such that they are less likely to be consumed as foods by living systems.
- The chemical bond modifications consist of dehydration, conversion of aliphatic bonds into aromatic bonds, and the consolidation of those aromatic bonds into local graphene complexes

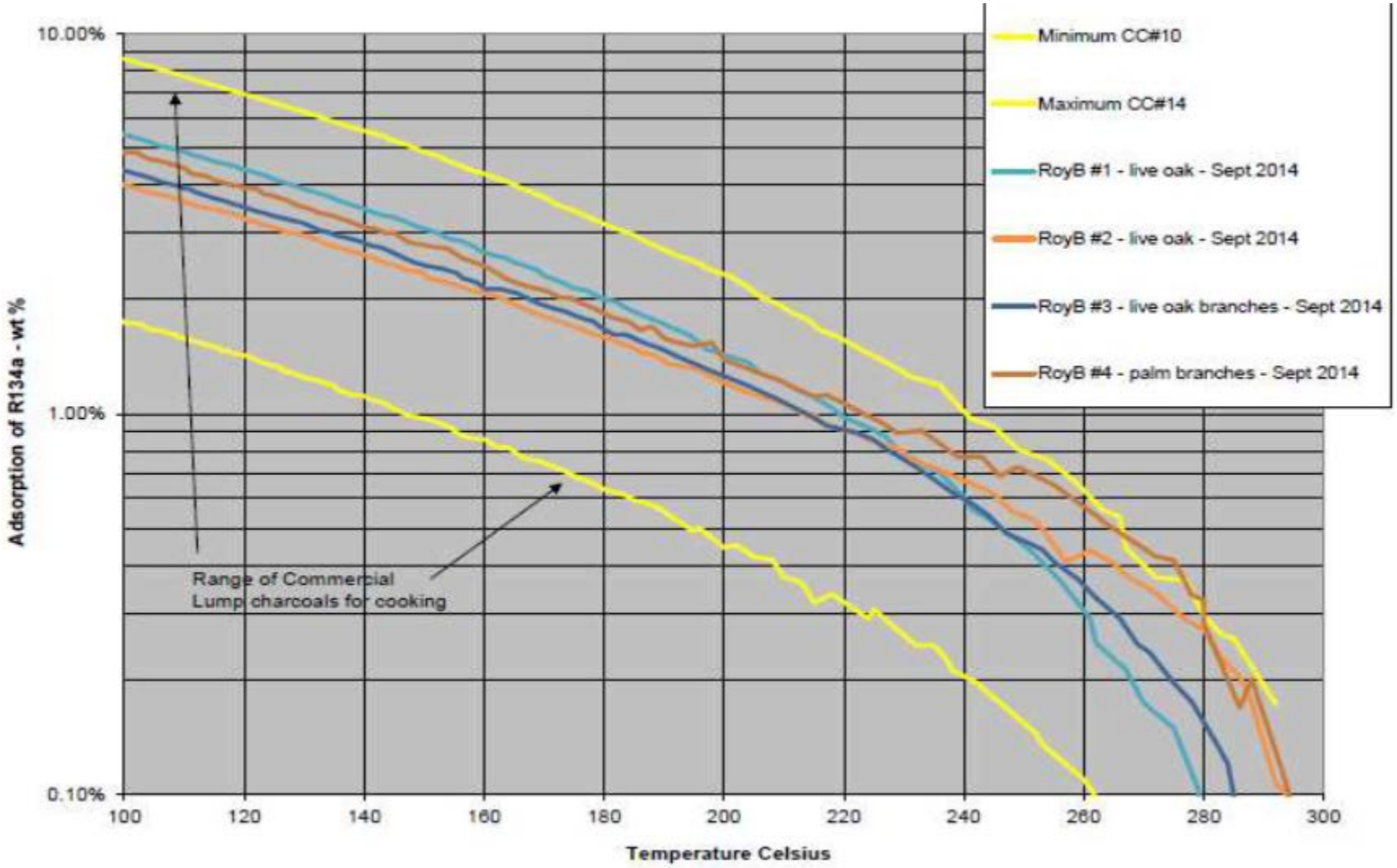


Micro-domain graphitic material

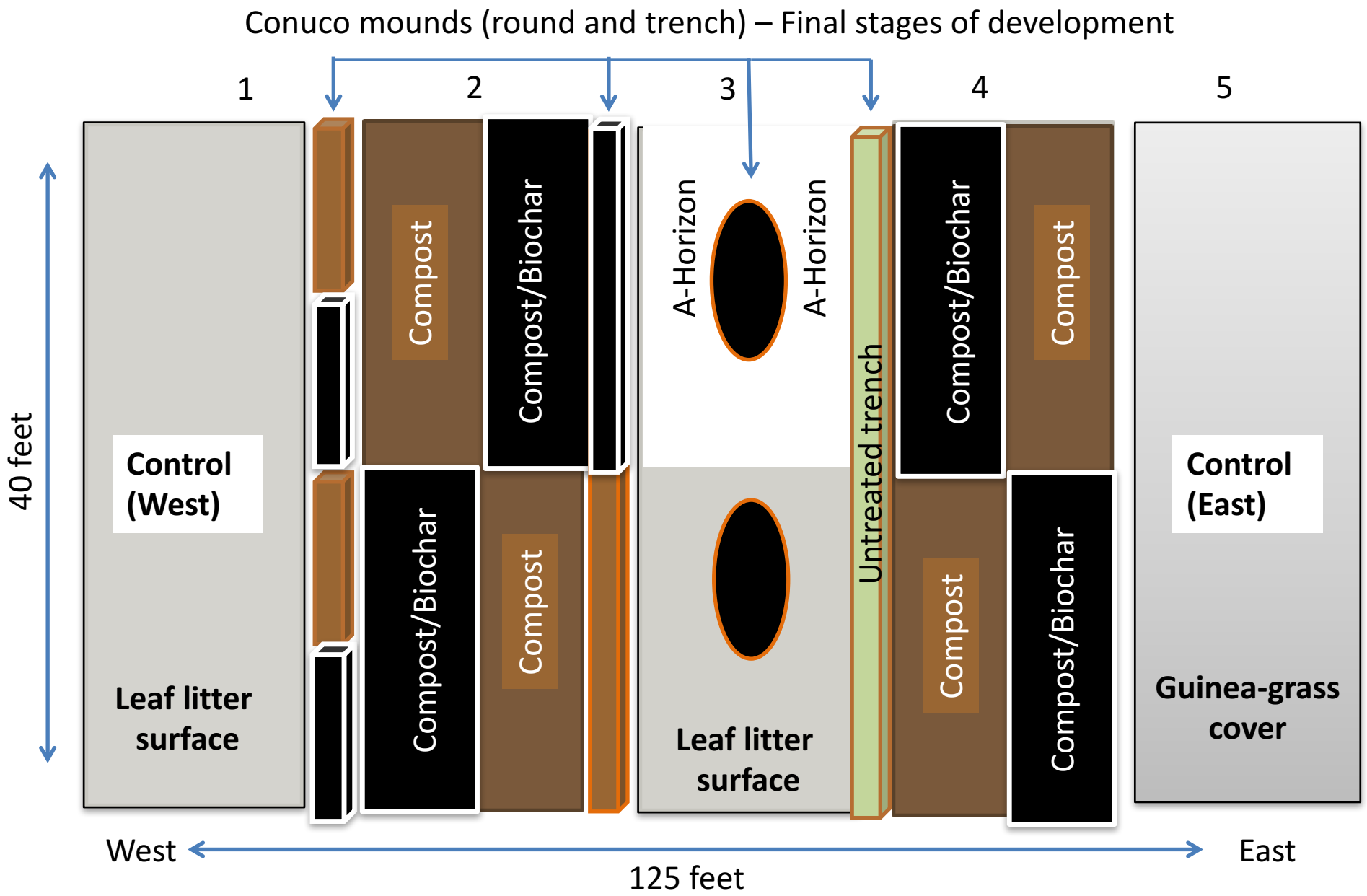
Making biochar



Gravimetric Adsorption Capacity Scan (GACS) Analysis



Research plot Illustrated



Biochar

- Collaborators in Haiti decided to charge the soil with urine. Volunteer sorghum plants emerged from pile after several weeks

Urinal at SAKALA, Cite Soleil

Millet planted on pile of char

Char removed by shovel to show plant roots.

Expansive worm castings on char synergy at ECHO

Earthworm Activity

Earthworm (P. corethrurus) activity

- **Explanation for the genesis of this deeper ‘O’ horizon compared to that found in control areas is the cumulative activity of earthworm communities.**
- Topoliantz and Ponge (2003) have shown that the burrowing behavior of *P. corethrurus* and other earthworm species create a network of vertical and horizontal channels in topsoil.
- **By virtue of the feeding and excretion patterns of earthworms, these channels act as tubular veins of organic matter between the organic (‘O’) horizon and deeper ‘A’ horizon, accommodating fungal mycelia and plant roots as the soil ecosystem improves.**
- The improved conditions cause the organic horizon to deepen.

Anthroposols

- In the historic sense, Anthroposols are soils with prominent characteristics that result from human activities over centuries.
- The parent material may be any soil material that has been modified through cultivation or by the addition of organic material (FAO, 2001*b*).
- Terra Preta do Indio or Indian Black Earth is the local name for certain dark soils found in the Brazilian Amazon region and several other countries in South America.
- Terra Preta Anthroposols were created on Podzol (sandy) parent soils by pre-Columbian Indians whose cultivation within them and occupation near their sites were abandoned after the invasion of South America by Europeans

Anthroposols

- Ancient Anthroposols are also identified in parts of Western Europe where calcareous soil materials were moved to areas within England and Ireland in which acid parent soils naturally existed.
- With the additions of the calcareous materials the acid soils turned into Terric Anthrosols (Terric horizon) which is largely composed of a surface layer of mineral soil material with superior properties for arable cropping than the original parent soils (FAO, 2001).

Anthropedogenesis!

Before

12 weeks After

Subplot ID	Sample	ppm P	ppm K	ppm Mg	ppm Ca	pH	%-OM	CEC	EW Count
Subplot 1	#1 Control	21	52	513	1989	7.3	2.36	18.66	0
Subplot 1	#2 Control	17	28	796	2767	7.2	4.16	24.21	0
Subplot 1a	#1 Control	22	53	513	1987	7.2	2.38	18.72	0
Subplot 1b	#2 Control	19	30	779	2766	7.2	3.91	24.3	0
Subplot 2	#1 compost; no biochar	36	28	369	2235	7.5	1.46	15.96	0
subplot 2c	#1 compost; no biochar	37	28	347	2387	7.5	1.57	15.88	2
Subplot 2a	#2 biochar/compost	69	79	375	5395	7.9	4.58	33.13	18
Subplot 2b	#3 biochar/compost	56	61	283	2195	7.9	2.84	15.34	6
Subplot 3	#1 Control	16	26	430	1954	7.5	1.53	16.42	4
Subplot 3	#1 compost; no biochar	32	29	617	1974	7.6	3.22	16.4	0
Conuco X	#2 biochar/compost	45	33	394	1969	7.2	3.47	15.12	36
Conuco Y	#3 biochar/compost	48	79	725	3514	7.2	3.47	15.12	22
Subplot 4	#1 compost; no biochar	35	19	291	2544	7.6	3.12	17.19	0
Subplot 4c	#2 compost; no biochar	35	18	305	2563	7.5	3.14	17.38	0
Subplot 4a	#2 biochar/compost	465	164	723	2801	7	4.02	28.86	12
Subplot 4b	#3 biochar/compost	803	248	1025	3913	7	5.2	40.51	21
Subplot 5	#1 Control	30	26	432	1870	7.5	3.33	14.69	0
Subplot 5	#2 Control	31	34	453	3222	7.7	2.78	26.19	0
Subplot 5a	#1 Control	31	26	436	1870	7.5	3.3	14.63	0
subplot 5b	#2 Control	31	31	457	3235	7.7	2.8	26.32	0
Conuco A	#1 compost; no biochar	41	145	1722	6105	6.9	6.94	55.2	6
Conuco A	#2 compost; no biochar	43	147	1736	6110	6.9	6.96	54.9	5
Conuco A	#2 biochar/compost	151	251	748	5287	7.5	7.5	43.11	22
Conuco A	#3 biochar/compost	214	317	861	7092	7.7	4.98	55.39	21
Conuco B	#1 compost; no biochar	36	82	871	3370	7.5	2.29	25.04	7
Conuco B	#2 compost; no biochar	36	87	819	3368	7.4	2.38	25.04	4
Conuco B	#2 biochar/compost	60	113	970	4168	7.2	5.07	33.82	25

Biochar is significant for soil creation

Two-Way ANOVA With Replication

Source of Variation	*SS*	*Df*	*MS*	*F*	*P-value*	*F crit*
Sample	7861774.737	12	655147.9	2.697464	0.003732406	1.860124
Columns	237297644.4	6	39549607	162.839	2.01032E-46	2.199905
Interaction	29806581.94	72	413980.3	1.704496	0.008136876	1.439805
Within	22101670.82	91	242875.5			
Total	297067671.9	181				

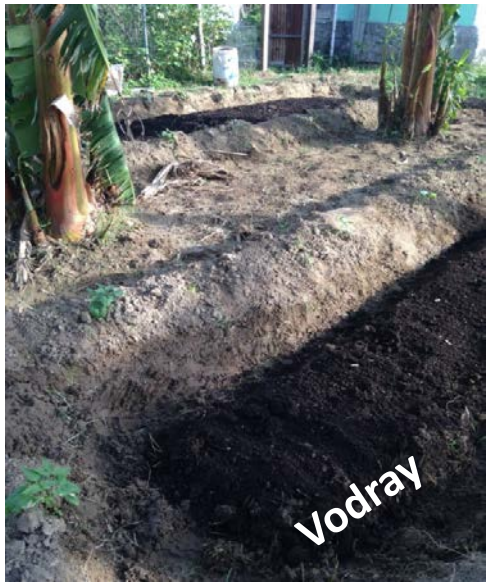
Result

- ANOVA indicates strong significance of biochar on pedogenesis

Outcome

- The carbon factor of biochar is essential to the regeneration of soils in degraded or low SOM environments

Communities of Practice



IFES Collaborators – Plot Establishment

3. REMUSOV, Vaudreiil

Before Photo: Irrigated trench system

After Photo: Four plots of compost and biochar (Anthropedogenic horizons) placed on parent soil in traditional trench irrigation system

Restorative Anthropedogenesis?

Restorative Anthropedogenesis

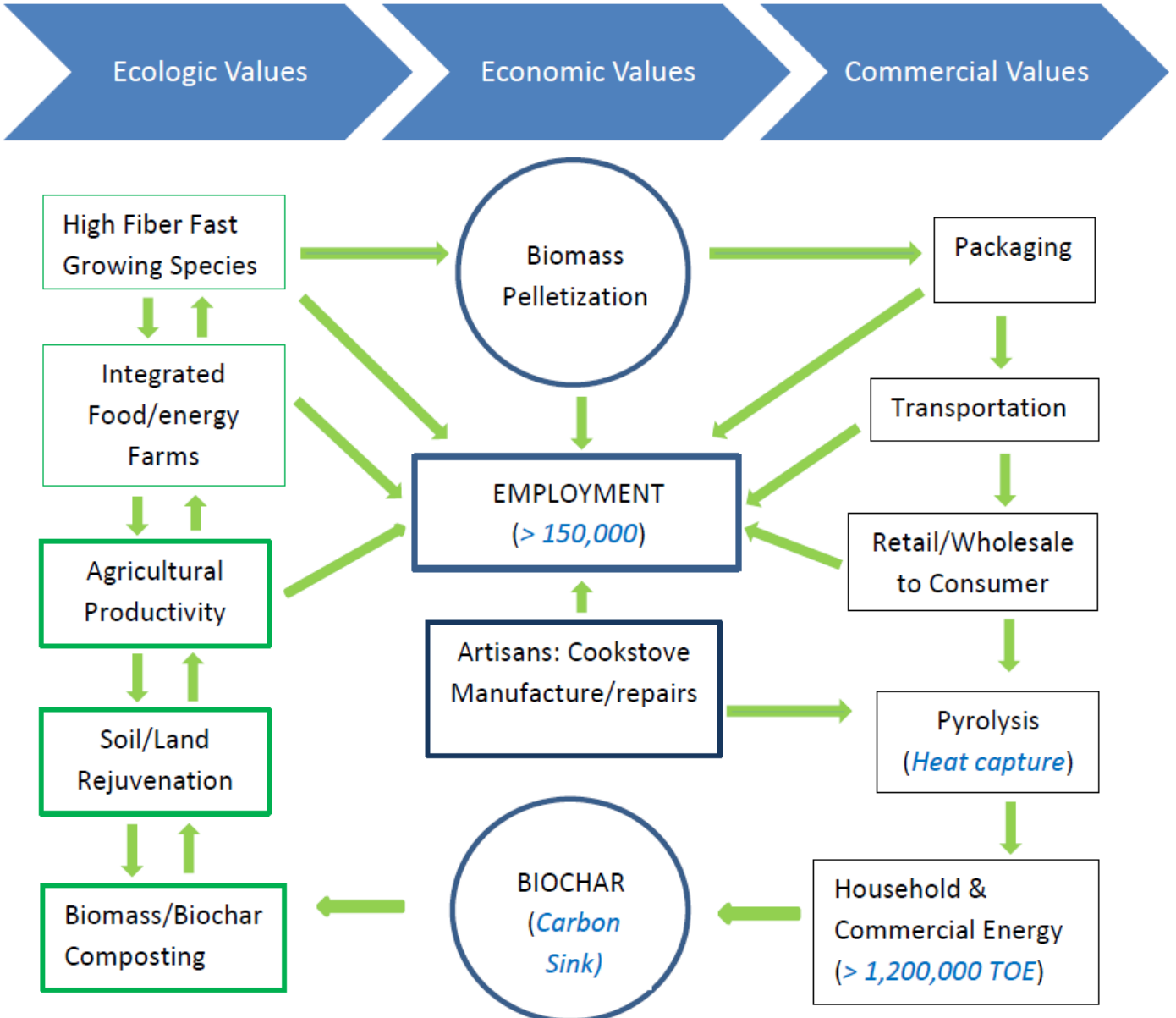
Changing the food-energy paradigm

Leucenia wood chips

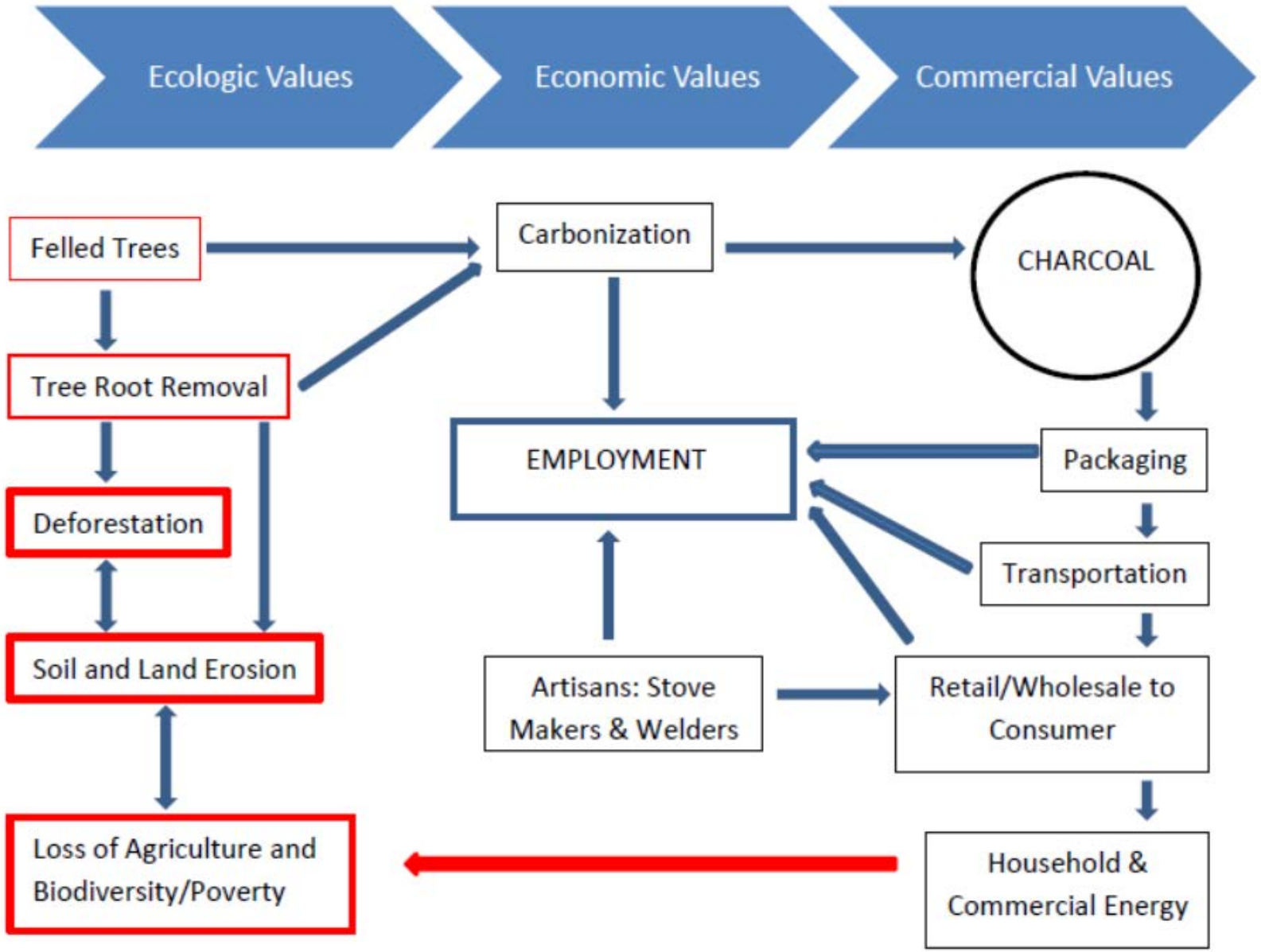
Biochar cookstove

Weighing the biochar

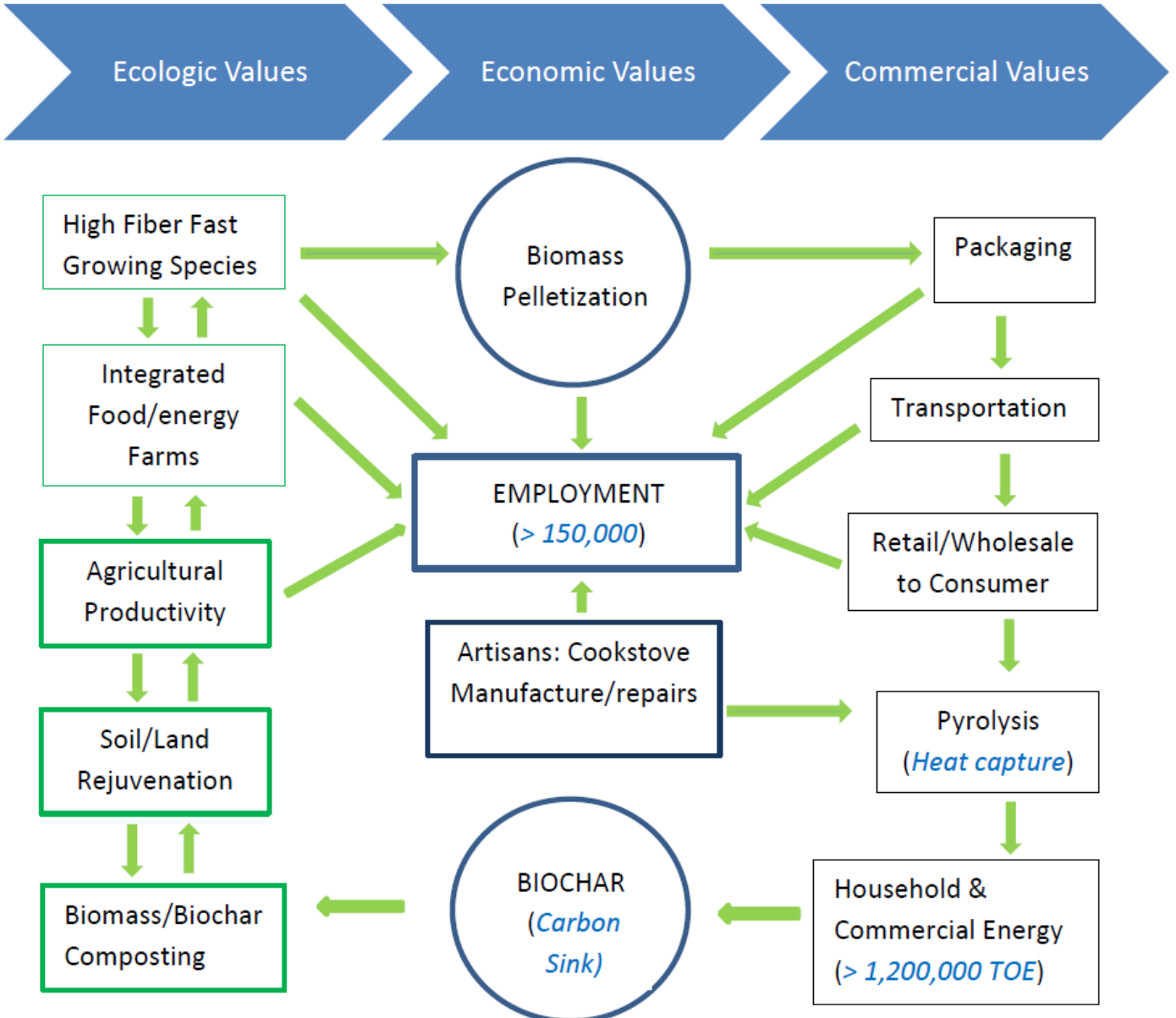
IFES Response – A Biomass/Biochar Value Chain



The Charcoal Consumption Chain



IFES Response – A Biomass/Biochar Value Chain



Important Findings

- Finding #1: Haiti's ecological demise has its roots in colonial biomass harvesting
- Finding #2: Anthropogenic vulnerabilities and ecological crisis areas are identifiable
- Finding #3: Energy poverty is equal to food insecurity in Haiti
- Finding #4: An integrated food-energy system (IFES) approach is viable in Haiti

Recommendations of the Research

- **Recognize the biomass energy sector** as a legitimate contributor to the Haitian domestic economy and ensure its inclusion in governmental development projects through targeted funding regimes
- Directly **address the knowledge intensity of IFES** by providing relevant community based education, participatory research, knowledge dissemination, and technical support among rural communities
- **Incentivize the quicker uptake of IFES by making it easier to afford** in the first place, especially those components which involve energy technologies such as biochar approaches and improved cookstoves
- **Provide rewards to community adopters** of those systems that reduce externality costs and generate non-monetary benefits such as ecosystem services – flood control, clean water, and increased biodiversity
- **Advocate international policies** towards Haiti that include innovations such as payment of 'biochar soil remediation credits' to communities of practice involved with soil remediation efforts

Recommendations of the Research

- Establish and **finance habitat-specific afforestation projects** based on the principle of ‘right plant in the right place’, and combine reforestation projects with soil creation strategies
- **Develop community restoration funds** aimed directly at communities involved with lowering their dependence on natural forests for their energy needs
- **Design an agro-ecological production system** suited to the specific ecological conditions and social needs of Haiti
- **Accommodate ‘ecological investments and trade’ dynamics** by which biomass resources of indigenous plant organisms may flow into Haiti from the Dominican Republic, so that endemic species lost or threatened in Haiti may be reestablished
- **De-emphasize the importance of non-governmental organizations with self-created mandates**, focusing development aid toward communities of practice in ways that incentivize change and reward results

Urban oasis offers hope to Haiti's poorest

http://www.cnn.com/2013/07/08/world/americas/urban-oasis-offers-hope-haiti/index.html

By Philippe Cousteau and Matthew Knight, for CNN
Updated 6:17 AM ET, Mon July 8, 2013

Environment

Air pollution million a year

More than two are dying ever effects of outd pollution, acc study.

The rise of ec gardens

What's better locally grown vegetables? H fresh, locally-g fruits and veg within an easy home or office

Thank You!

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