Cool the Climate, Clean the Environment, Improve Public Health, Reduce Rural Poverty with Small-Scale Biochar

by Dr. D. Michael Shafer

Part 1: The Ubiquity of Corn

Introduction

This article is the first of a five part series that addresses a large, unknown threat to the global climate and the health of billions of people: smoke from small farmers in the developing world burning billions of tonnes of crop waste annually.[1] Rather than taking on this huge topic in the abstract, I want to focus on a single, well-known crop, corn, and the poor families that farm it. Important in its own right, corn is a leading example of a crop that has succeeded commercially in global agricultural commodity markets. It is an exemplar of the commodity crop grown locally for consumption globally, specifically, as feed for animals raised for global meat markets.

In brief, Cool the Climate series does the following. Here I establish how much corn is grown in the developing world and how much corn crop waste remains to burn.

In Part 2, I answer the question that, unless answered compellingly, results in articles like this being filed under "interesting" – forever: why should anyone care?

Part 3 then does what few articles do: it offers a practical, low-cost, cost-effective, replicable and sustainable – even profitable – solution.

In Part 4, I discuss market issues because my solution builds on a social enterprise business model, not the usual charity model that dominates discussions of climate change, the environment and public health. The market, I argue, is where the problems and the potential confront those interested in cooling the climate, cleaning the environment, improving public health and reducing rural poverty by cutting crop waste burning in the developing world.

Part 5 makes the case for small-scale biochar as the only means available to address these problems where they arise - and where the need lies - in the fields of individual, small farmers.

Authors of all ideological stripes have written about many of the issues raised by the global expansion of corn production. Some discuss corn as the show-child of how globalization either drives food insecurity or renders the concept meaningless. Others contend that large-scale mono-cropping is inevitably disastrous or that the threat is misconstrued. Some disclaim on the perils of genetic diversity lost and others on the virtues of seed company breeding programs. Some warn of the risks of "franken-foods," others tout the benefits of reduced chemical use.

A different perspective on corn

I have no desire to enter this crowded fray. I am neither polemicist nor geneticist. I work out in hot, dusty fields with poor farmers. I want to talk about corn from a different perspective and in different terms. Here in "The Ubiquity of Corn," the first article in the Cool the Climate series, I want to talk about corn as a hugely wasteful crop because this explains the size of the corn crop waste burning problem.

- At harvest, a farmer has 63% stalk, 11% cob and 4% husk and just 22% kernel. 78% of his crop is inedible waste.[2]
- How much corn in produced worldwide is unclear. Despite the common sense notion that "corn production" refers to corn kernel, it often refers to kernel, cob and husk, which is easier to track. Because it is more conservative, I adopt this definition and use the 63% stalk to 37% "corn" kernel-cob-husk "waste to worth" ratio.

Village De-kernelling Machine in Action

A typical, rural corn de-kerneling site. The 22% kernel is filling the pickup truck. The pile of cob and husk is 15% of total biomass. When the pile grows too big, it is burned.

The Ash is worthless.

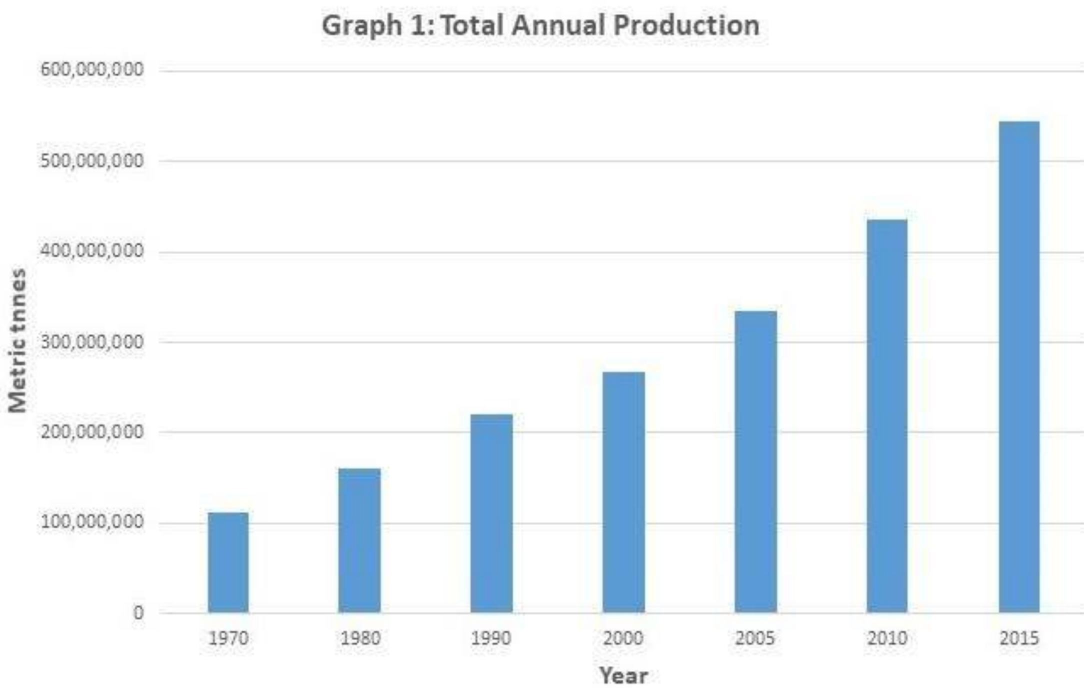
The Rise of Corn

"Toto," Dorothy famously observed, "I don't think we are in Kansas anymore." What she meant is that she did not see corn stretching from horizon to horizon. But that was then. Dorothy would be less certain today. She could land in Argentina or Burma, Laos, Malaysia, or Zambia and be surrounded by corn.

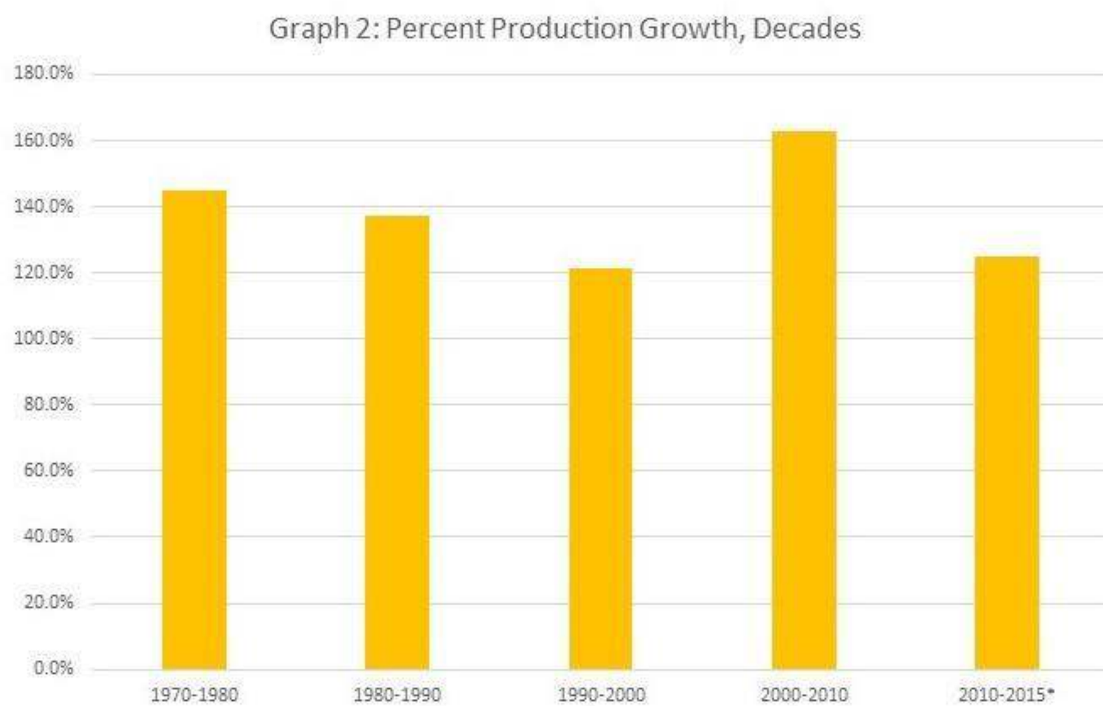
What happened in the years since that fateful tornado? Decolonization, containerization, integrated markets – and wealth. The rise of a global middle class with the money to eat meat and ice cream. To raise all those animals requires lots of cheap, easily transported and stored, essentially indestructible feed.[3] Given that corn will grow almost anywhere under almost any conditions and is transportable, storable and indestructible, it is not surprising that corn production spread like wildfire to become *the* cash crop of the cheap, marginal lands of the developing world's fringe.

The Size of Corn

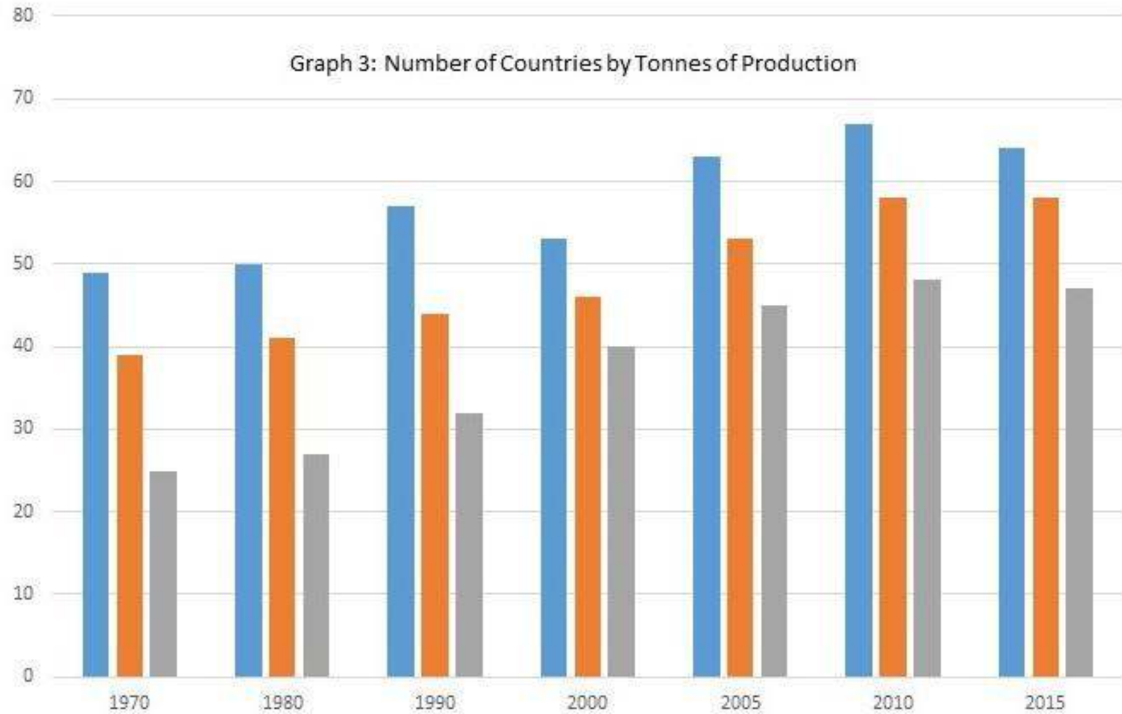
The rapidity and thoroughness of corn's penetration of the developing world is an amazing story just by the numbers. The Food and Agriculture Organization (FAO) keeps corn production statistics for every country in the world. Graph 1 shows the increase in developing world corn production from 111 million tonnes in 1970 to 544 million tonnes in 2015. (All figures from FAOSTAT.[4]



To give a sense of the rate of increase, Graph 2 plots the decade-on-decade percentage increases required to accomplish this 490% increase in 45 years – 200% in the first 15 years of the 21st century.



Graph 3 shows how rapidly individual countries became big producers. In 1970, 49 countries produced 125,000 tonnes of corn or more annually, forty years later, 67 did.



Blue = 125,000 tonnes/year or more Orange = 250,000 tonnes/year or more Grey = 500,000 tonnes/year or more

For us, however, the point is not the corn; the point is the waste left behind.

The Wasteland of Corn

The story of the amazing expansion of developing world corn production is also the story of the far more amazing expansion of corn crop waste to be burned. Remember, even if you define “corn production” as the amount of kernel, cob and husk farmers take out of their fields; “corn production” is just 37% of the total corn crop. The remaining 63% is corn stalk that is left as waste to be cleared, normally by burning, before the next planting.

This is 63% of the annual corn crop.

Once fired, dead corn stalk burns for kilometers.

Not to put too fine a point on it, if developing world farmers produced 544 million tonnes of corn in 2015, they had 1.5 billion tonnes of corn stalk to clear afterwards.

As we will see in Part 2 of the Cool the Climate series, "Why Care that Corn Burns Dirty?" open field burning even a small portion of 1.5 billion tonnes of corn stalk has nasty consequences for the climate, the environment and the humans who inhabit it.

[1] "Tonne" denotes "metric ton" (1,000 kg or 2,200 lbs.).

[2] These figures refer to corn grown under developing world conditions on steep slopes with degraded soils and no fertilizers. Warm Heart data from North Thailand where farmers' rule of thumb is 6 parts kernel to 3 parts cob to 1 part husk for the dry "corn on the cob" they bring in to be dekernelled.

[3] FAO asserts that the growth of the livestock sector is a key driver of world agricultural growth. World meat consumption has increased 5-6% per year and milk consumption 3.4-3.8%, although "disproportionately concentrated in the industrial countries." http://www.fao.org/docrep/005/y4252e/y4252e05b.htm

[4] As regards figures, "developing world" refers to a master list of approximately 93 countries that varies in number as, for example, "Former Sudan" becomes "Sudan" and "Southern Sudan." The list ignores many tiny island states such as Kiribatu and Vanatu and throughout uses the single entry for "China."

Part 2: Why Care that Corn Crop Waste Burns Dirty?

This, the second in a series addressing the climate, environmental and human health consequences of the open field burning of corn crop waste, is about understanding self-interest. Specifically, "Why Care" makes the case that burning corn crop waste pushes climate change enough to worry all global inhabitants and causes such significant public health damage that developing world governments should worry, as well.

Why Burn?

Poor farmers burn of necessity. They have no tractors to turn under stalk. As soon as the harvest is finished, most healthy adults leave to find dry season work in the cities, leaving the infirm, disabled and elderly, all often malnourished, to clear fields for the next crop. The only realistic means is fire.[1]

Photo credit: Adri Berger, still from film "The Seasons: A Hmong Story"

How Much Corn Crop Waste Is Burned?

In “The Ubiquity of Corn,” I used FAO statistics to show that in 2015 developing world farmers grew 544 million tonnes of corn defined as cob, husk and kernel and therefore grew 1.5 billion tonnes of corn stalk left in their fields as waste. Many authors studying specific areas conclude that farmers burn between 50 and 90 percent of crop waste. I will use more conservative figures: 10 and 25 percent, because in many places poor farmers feed corn stalk to animals or use it in construction, and in others rich farmers with tractors plow their stalk under – and also to avoid being dismissed as a crank. (A 2018 study from North Thailand reports that 41% of corn farmers burned.)

In “Why Care,” I will assume that farmers burn “just” 150 (10%) or 375 (25%) million tonnes of waste annually. (By way of perspective, a major scientific study suggests that in Asia alone 248 million tonnes of crop waste are burned annually.)

What Happens When Corn Crop Waste Burns in the Field?

It is comforting to believe that burning corn stalk is just burning a renewable resource; it simply returns CO2 to the atmosphere that photosynthesis removed earlier. In fact, burning corn waste releases not only “carbon neutral” CO2 but also large quantities of other, long-term greenhouse gases (GHGs) more warming that CO2, dangerous smog precursors and killer PM2.5.

- **Climate change:** when burned, each tonne of corn stalk releases 1.585 tonnes of “carbon neutral” CO2. It also releases 1.072 tonnes of eCO2 (CO2 equivalent) as methane (CH4) and NOx, greenhouse gases that are 25 and 298 times as warming as CO2.[2]
- **Smog:** Field burning a tonne of corn waste releases 63 kg of CO, 2.72 kg of NH3 (ammonia), 77.1 kg of NMOCs and 3.11 kg of NOx, all important smog precursors.
- **Smoke:** Field burning a tonne of corn waste releases 6.26 kg of PM2.5, particles so small that they will pass through the walls of the lungs and into the bloodstream.

What Are the Consequences of Burning 10% or 25% of Developing World Corn Stalk?

- **Climate consequences:** Burning 150 million tonnes of corn waste emits 161 million tonnes of eCO_2. Burning 375 million tonnes of corn waste emits 402 million tonnes of eCO_2. To put this in perspective, emitting 150 and 375 million tonnes of eCO_2 annually is equivalent to the eCO_2 emissions of 37 and 93 coal-fired power plants respectively. (Equivalencies courtesy of the EPA.)
- **Environmental consequences:** Burning 150 and 375 million tonnes of corn waste emits 30 million and 125 million tonnes of smog precursors respectively. A study of smog over Perth, Australia found annual emissions of NOx in the range of 70,000 tonnes and CO under 300,000 tonnes. The World Health Organization (WHO) estimates that smog kills 3 million people annually. (See WHO.)
- **Public health consequences:** Burning 150 and 375 billion tonnes of corn waste emits 939,000 and 2.3 million tonnes of $PM_{2.5}$ respectively. WHO ranks $PM_{2.5}$ the 5th biggest killer in the world today, causing 4.3 million deaths per year, equivalent to TB, HIV, malaria and hepatitis B *combined*. One kg of $PM_{2.5}$ is equivalent to the smoke of 71,429 cigarettes; 939,000 tonnes of $PM_{2.5}$ – 939 million kilograms – is equivalent to the smoke of 67,071,831,000,000 cigarettes. (Author's calculation based on 14 micrograms of smoke from a standard cigarette.) You understand why developing world farmers suffer high rates of heart attack, kidney failure, lung cancer, respiratory disease, and stroke, all commonly associated with $PM_{2.5}$ inhalations.

  (91% of $PM_{2.5}$ induced deaths occur in the developing world, of which 58% were due to strokes and heart attacks, and 24% from respiratory disease and lung cancer.)

Why Care?

Simple self-interest.

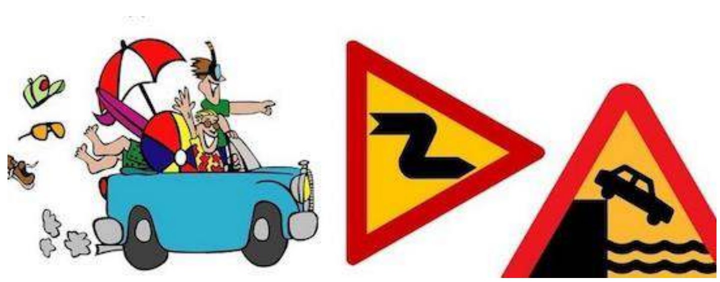
Today, developed countries struggle to reduce carbon emissions while maintaining energy intensive lifestyles, not least by making the costly switch from coal-fired power plants to cleaner alternatives. Self-interest suggests that there is reason to care that reducing corn crop waste burning just 10% would cut global eCO_2 emissions as much as decommissioning 37 coal-fired power plants – annually.


Coal fired power plant. Photo credit, Nian Shan, Greenpeace

Today, developing countries struggle with growing demands on unsteady budgets. Self-interest suggests that there is reason to care that reducing corn crop waste burning just 10% would save billions of dollars annually in healthcare costs and lost labor productivity. (The World Bank estimates that the cost of lost labor productivity alone is $225 billion. In East, South and Southeast Asia the resulting cost is as much at a full point loss in GDP. World Bank air pollution impact on labor productivity study.)

Paris v. Carbon Removal

The Paris Agreement of 2015 represents a huge diplomatic achievement – and left the climate change glass half empty. Parties at Paris agreed – sort of – to limiting the addition of still more carbon to a global system that everyone acknowledges is already beyond its holding capacity. The qualifier “sort of” refers to the continued right of “over-emitters” to buy the “unused” “emission rights” of others, therefore simply spreading carbon emissions more evenly around the world, not actually reducing them.



Simply reducing carbon emissions is like tapping on the brakes of a runaway car as you hurtle down a mountain road toward a missing bridge over a deep gorge. It may delay the inevitable ever so slightly, but like Wily Coyote, you are going down, even if you hang suspended for a moment over the abyss.

The critical issue today is drawing down the carbon overload through cost-effective carbon removal. We need to reverse climate change, not pretend that it is enough to "contain" it.

But how?

For a practical, low-cost, cost-effective, replicable and sustainable solution, please read Part 3 of this series, "Sows' Ears into Silk Purses."

[1] Many argue that burning sterilizes soil and leaves enriching ash. Both claims are false. The fires burn too far above the ground and too fast to kill eggs and spores in the soil. The ash is nutritionally worthless and so light that it blows or washes away without penetrating.

[2] Emission Factors (EFs) from S. Akagi, et al., "Emissions factors for open and domestic biomass burning for use in atmospheric models," Atmospheric Chemistry and Physics, (2011): 4039-4072. The EF for CH_4 is 5.82 kg/tonne and NOx 3.11 kg/tonne. The EPA Global Warming Potentials for CH_4 and NOx are 25 and 298. Thus, (5.82 x 25) + (3.11 x 298) = 1,072 kg. I ignore black carbon because of confusion about its GWP. To understand how variable EF figures can be, a recent study of Mae Chaem District, Chiang Mai Province, Thailand where Warm Heart conducts much of its research, used EFs for CH_4, NOx and PM2.5 that are much lower (2.4, 0.5 and 6.00 as opposed 5.82, 3.11 and 6.26), but a black carbon EF identical to the one we would have used.

Part 3: Biochar Social Enterprise – A Solution?

Corn is here to stay. There is no “better” crop to replace it for farmers of the marginal lands at the fringe of development and no prospect that meat consumption will plunge any time soon. So what is to be done – can anything be done – to reduce the impact of burning 150 to 375 million tonnes of corn waste annually?

This, the third in a series addressing the climate, environmental and human health consequences of the open field burning of crop waste, offers a practical, low-cost, cost-effective, replicable, sustainable – even profitable – solution to the problem of crop waste burning.

The Village-Scale Biochar Social Enterprise Solution

What is needed is a business model that offers farmers and villagers a real incentive not to burn right there where they live. How to implement such a solution?

Teach small farmers to convert their waste into biochar and either to use it as a soil amendment or sell it to a member owned, village cooperative that processes it into value-added biochar products such as smokeless briquettes for cooking or fertilizer.

Why small farmers? Because corn crop waste is widely dispersed across steep mountain slopes and is prohibitively expensive to collect. To stop the burning, it is necessary to give the burners, the small farmers themselves, a better (ideally profitable) alternative way to clear their fields. Admittedly, individual farmers and village cooperatives will have a vanishingly small impact on this global problem, but this is not the point. Imitated by millions of farmers in hundreds of thousands of villages, a village biochar social enterprise might eliminate it.

This business model offers individual farmers the ability to earn large amounts (relative to their current incomes) and village biochar cooperatives the ability to pay generous dividends to members. (Many express skepticism that farmers will make biochar at all. Warm Heart's experience shows that they will even in wealthy countries such as Thailand. As long as there is a market, the poor will perform.) The connection is simple: the more money each biochar converter makes, the greater the incentive for other farmers to make biochar and the less waste burned. Likewise, the more profitable each cooperative, the greater the incentive for other villages to imitate the social enterprise model and the less waste burned.

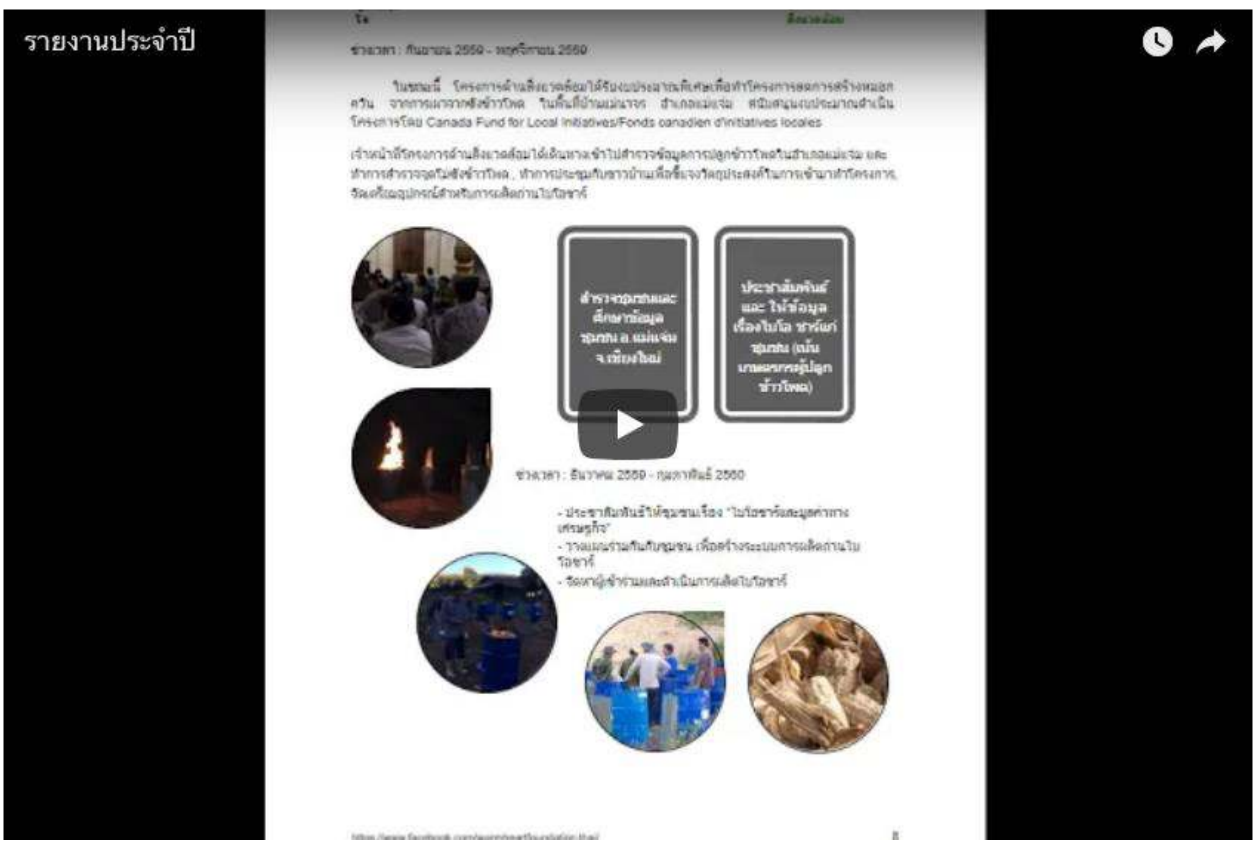
This five-minute video shows anyone how to make a basic barrel TLUD biochar machine. In North Thailand, materials, including a used, high-quality barrel, costs $85. Construction takes about an hour and a half.

What Is Biochar? Why Make It? Why Use It?

To make biochar, biomass such as crop waste is pyrolyzed (heated without oxygen). This can be done using extremely simple technology. In fact, corn stalk is easily pyrolyzed in a trench in the ground. Producing biochar sequesters CO_2 at a ratio of 3:1, CO_2 to biochar, making biochar production the only cost-effective carbon negative process available today.

Biochar production also averts the emission of the GHGs CH_4, and NO_x. It averts the emission of black carbon, the smog precursors NH_3 (ammonia), MNOCs, and NO_x, and $PM_{2.5}$, all of which are combusted or chemically broken up in the heat of the process. (For the scientific data, see "In-Field Biochar Production from Crop Residues," Tropentag Conference on International Research on Food Security, Natural Resource Management, 2015.) When used as a soil amendment, biochar reestablishes soil carbon stocks, restores degraded soils by improving soil structure, fertility and pH, raises yields, increases water penetration and retention, lowering drought risk to crops, and locks up heavy metals, agro- and industrial chemicals, reducing soil, water and food contamination.

If you read Thai, this slideshow walks you through the making, use and virtues of biochar.



A five minute video that teaches small farmers how to make biochar fertilizer. In field tests with rice, this fertilizer out-performed farmers regular synthetic fertilizer by 10%.

How Would a Village Biochar Social Enterprise Work?

A social enterprise converts social problems into profitable business opportunities that benefit all stakeholders. Contrary to the standard model of development that requires large inputs of outside cash and expertise in a limited number of locations and that disempowers community members, the social enterprise model capitalizes on the self-interest of local players who invest in their own projects to better their own lives, causing “development” to spread by imitation.

Put differently, social enterprise is a model for sustainable development and sustainable agriculture. There are great virtues to improved farming technology, seeds and so on, as long as they are appropriate to farmers’ actual conditions. The risk is always that when introduced by well-intentioned outsiders, these inputs bomb, witness the myriad failed development schemes that litter the developing world. There are two related problems that defeat sustainability. Outside intervention changes local relative prices making project innovations profitable.

Once interventions stop, prices return to normal and many innovations are no longer profitable or sustainable. Cost-sensitive small farmers drop them.

Replicability and scaleability are essential to outside planners who equate the size of problems with the size of the required solution. The result of rushing to replication is often large-scale failure.

Social enterprise avoids these problems because it starts from the self-interest of local stakeholders and spreads through the imitation of others, like individuals. It is the very do-it-yourself, low-rent messiness of the social enterprise approach that makes it so apt for sustainable development and sustainable agriculture – even if it violates all of the niceties of bureaucratic and budget driven management.

The numbers vary wildly from country to country. Here let me use numbers from a rich, high cost country, Thailand, because I know them well. I assume a minimum cost operation of the sort that poor farmers would use, but to be conservative, I use Thailand's national minimum wage of $10 per day (actually paid nowhere in the mountain, corn growing areas). Please note below that although equipment costs may be higher in poorer countries, labor costs, especially when paid by villagers to each other, will be far lower.

Costs			
• Equipment			
o Mixer			$1,500
o Briquetter		$1,500	
o Kiln			$1,500
• Staff			
o Manager (6 months)		$1,680	
o Factory workers (4) (5 months)	$4,800		
• Biochar			
o Made by farmers @ $10/day	$24,000		
• Manure			
o Admixture for fertilizer		$140	
• Bags			$440
Total Costs			**$35,560**
Revenues (assuming 80% briquettes, 10% plain biochar, 10% fertilizer)			
• Briquettes @ $0.40 per kg	$46,000		
• Biochar @ $0.33 per kg		$4,800	
• Fertilizer @ $0.30 per kg	$8,160		
Total Revenues			**$58,960**
Profit/(Loss)			**$23,400**

These numbers are only suggestive, not definitive. They do suggest, however, that farmers without a dry season income might want to make biochar for a local cooperative and that village members might think it reasonable to borrow the equipment costs and working capital requirements to start a biochar social enterprise.

This guy made so much money in the first two months that he bought a pair of water buffalo. He named them "Oon" and "Jai" ("Warm" and "Heart" in Thai, the name of our organization).

But Can a Biochar Social Enterprise Work in the Real World?

At Warm Heart we know that this business model works because we have tested it and continue to test it. (See the header photo and the photo above.) Farmers are delighted to make biochar for a price that permits the profitable sale of processed products. At the end of the fiscal year, there is enough profit left in the bank to pay a nice dividend to all biochar social enterprise coop members. The challenges of government interference and social discord within broken villages are real but manageable.

“Rak Din” (Thai for “Cherish” or “Restore the Earth”), our own demonstration social enterprise, is proof that a profitable biochar-products “factory” can be pretty low rent and profitable, although demand creation is very demanding.

Ironically, although the market enables this simple social enterprise solution to major problems, the market poses the single biggest threat to it, as well.

Part 4: Establishing a Market for Biochar

What's a Market Anyway?

We know what a market is. It's where sellers exchange stuff with buyers and both leave feeling richer because they value the stuff exchanged and liked the price. Price? Supply and demand, Economics 101, right? Wrong. Markets require "property rights" created by power and expressed through rules, laws and institutions that establish weights and measures, security of contracts and currency, and so on. These, however, only help property rights do their main job: determine who profits from transactions. They may require, for example, price to reflect costs to society such as associated health costs, that is, they may allocate some value to "society," as opposed to private actors.

So what?

To understand to the potential of small-scale biochar requires understanding markets.

Demand Creation

Steel blades blunt bronze blades and are therefore more valuable. Biochar is not obviously valuable or superior to anything. Its value must be established by demand creation.

A small-scale biochar social enterprise must sell products in distant markets. Unless it can, it will lack the funds to buy biochar from farmers who will then not make it. Value in an outside market is important locally because it signals "value" to farmers and validates claims that using biochar will benefit them.

School children planting gardens using biochar fertilizer as part of demand creating field test program.

Demand creation is hard work. Social enterprises can grow it incrementally, for example, by capitalizing on the popularity of charcoal briquettes to sell biochar briquettes that are superior to traditional ones. (Biochar briquettes do not smoke or smell. They light faster, and burn hotter and longer than traditional charcoal.) This can provide the time required for farmers to appreciate the value of biochar as a soil amendment. Accelerating the process, however, requires energy and money for training, sales and marketing.

Kwanpirom (Aom) Suksri, Rak Din's marketing boss, with a happy farmer in a still from TV story about Rak Din.

These problems are common to all new products. Demand creation for biochar faces bigger problems

Barriers to Demand Creation

The rural farmers who burn largely live beyond agricultural extension in a world ruled by synthetic fertilizers. Most get their agricultural information from fertilizer and seed salesmen. If they hear anything from official sources, it is about synthetics.[1] Fertilizer salesmen do not tout homemade products. Extension agents have never heard of biochar and preach synthetics.[2] Outsiders pay national public health costs. Official development agencies, international NGOs and the big international organizations have not heard of biochar and have a different agenda for the poor.

This agenda is a key barrier to biochar adoption. The problem stems from the embedded missions of international NGOs and organizations. The laudable Sustainable Development Goals (SDGs) – to provide health care, houses, food, etc. – involve the external gifting of systems, services and supplies to passive recipients. What little agricultural aid is extended – only about 4 – 6% of total aid – goes to larger-scale projects with export potential. (The only major study of aid and investment in agriculture over time finds the data poor, but the overall results discouraging. Trends are downward facing everywhere except Asia. Despite promises made after the 2008 food crisis, ODA in agriculture continues to flag – it has not yet returned to the level of the 1980s – while commodity aid (gifting) has rapidly become the second largest component of ODA. (See Sarah Lowder and Brian Carisma, "Financial Resource Flows to Agriculture.")

Wonderful intentions, old agenda, although not necessarily. It is possible to reduce poverty and improve food security by increasing the productive prospects of the poor. It is easier, however, to extend populist programs for the poor and food "aid." This disconnect between "policy," understood as what is planned and "policy," understood as what happens is seldom recognized, but critical to understanding the persistent failure of good intentions.

For governments, export agriculture makes sense. Global trade in agricultural products is booming; countries that get to commercial scale in high value crops such grapes or tropical fruits profit handsomely. Agricultural entrepreneurs positioned to glom onto such opportunities profit handsomely, too. What is unclear is how this benefits the rural poor who constitute a majority in many countries.

Big is the way to go. Scale trumps all in agriculture, although it renders the original landholder-farmers into day laborers and makes those with access to governments and funders wealthy.

Two assumptions hide here. (1) The rural poor cannot help themselves, hence the gifting strategy and focus on the "dynamic few." (2) Optimistically, rural-urban migration will empty the countryside and commercial agriculture will grow fast enough to embrace the remaining rural poor in expanding networks of "modern" agriculture bound together by rapidly developing distribution systems serving a sophisticated hierarchy of markets. When what is left of the world's two billion small rural farmers are engaged in a modern agricultural economy, there will be no need for biochar nor concern about crop waste burning.

I am less optimistic. My concern about crop waste burning and interest in small-scale biochar begin from the assumption that the rural poor of the developing world will be with us for a long time.

Readily Available Demand Creation Drivers

DEADLY EXPOSURE

According to WHO, one-eighth of the total deaths in the world is caused by air pollution — both indoor and outdoor

DISEASE	DEATHS BY Outdoor pollution	Indoor Pollution
Ischaemic Heart Disease	40%	26%
Stroke	40%	34%
Chronic obstructive lung disease	11%	22%
Lung cancer	6%	6%
Acute respiratory tract infections among children	3%	12%

India, second most populous country in the world, cites WHO constantly about air pollution.

Is there no hope? Of course not. It would take little to create the demand to drive the replication of small-scale biochar social enterprises across the developing world. FAO, for example, could help with demand creation for biochar among farmers and WHO among the poor public. These organizations are global leaders that can speak to the entire world. All they need do is warn about burning, promote biochar and shape the literature disseminated globally. Imagine a village where FAO materials told farmers about restoring soil and improving yields with biochar. Imagine a market hung with WHO posters about smoke where women ask vendors if their briquettes are biochar because they want to ensure that their cook fires produce fewer particulates and harmful gases.

The Perils of Success

What threatens small-scale biochar? Market success. Why? It will invite competition from large-scale, low-cost producers. The social enterprise model will convert untouchable crop waste into biochar and deliver it to market at $136/ton (price converted from metric tonnes), solving critical climate, environment, public health and rural poverty problems. [3]Given a market, however, a large timber mill can buy a big pyrolyzer and switch from burning sawdust to dry lumber to pyrolyzing it, using the heat to dry lumber, and selling the "waste" biochar for $64/ton containerized at port, leaving the problems unsolved. No company will buy more costly small-scale biochar and managers of public companies that did could be sued for not financial malfeasance.

What would you do with the stuff? Currently, it is impossible to argue with the cost/profit logic.

Valuing the Climate and Lives

We are back where we started. What is a market? How are prices determined?

The property rights embodied in this market value the profits of the timber mill and buyers of cheap biochar over the broader “values” that small-scale biochar would provide to global citizens and the billions of people living in the developing world.

We talk about valuing the climate, environment and human life. We even spend money on spot interventions to foster this or that “green industry” or care for this or that population. We do not talk about the rigged market that invisibly disadvantages the climate, environment, public health and human life. These cannot be protected by temporary interventions; they require a systemic solution. Until we embed our values in the structure of the market itself, short-term, private profit incentives will continue to prevail. If we actually value the climate, environment and the lives of all humans, we must price these values into the market. We must change the property rights that prevail in global markets to recognize the climate, environment and human life and enforce this recognition of global social good.

[1] Warm Heart survey data of what farmers know and where they acquire knowledge. Details on request info@warmheartonline.org
[2] When Warm Heart presents field trial and international data to officials and extension workers, the response is “never heard of biochar.” In China alone the Ministry of Agriculture promotes biochar to reduce smoke from crop burning, lower fertilizer use and decrease heavy metal contamination of the food chain

[3] In a global context, small-scale biochar is not only available, but a relative bargain. The newest technology promises to capture carbon at a comparable price, $94 to $232/ton, but without addressing the problems and with huge upfront capital costs. Nature, 7 June 2018

Part 5: The Case for Small-Scale Biochar

So far, I have focused on the effects of burning corn waste and what to do about it. Here I examine small-scale biochar itself to show why it is the only means available to address the problems posed by all crop waste burning. Without it, we cannot avoid the consequences of burning for the global climate, the environment, and the lives of billions of people.

How Big Is the Bigger Problem?

In 2015, developing countries produced 1.5 billion tonnes of corn stalk, 705 million tonnes of rice straw, 200 million tonnes of soy hay and 310 million tonnes of wheat straw. The big four food crops generated ***2.7 billion*** tonnes of crop waste. Farmers may have burned 10% or 25% of this, ***270 million*** or ***674 million*** tonnes. Burning this much crop waste was bad for the global climate and the environment in which the global poor live. (Data FAOSTAT.)

A scene from anywhere.

Who Is Affected?

Climate change affects everyone; it is harder to estimate how many people smog and particulates from burning affect. The Food and Agriculture Organization (FAO) believes that 3 billion people live in the rural developing world, 2 billion in 475 million small farm households. If we count only the farmers who burn, we are talking 200 million (10%) or 750 million (25%) people. If we include all rural inhabitants – but not, for example, inhabitants of Delhi, Lahore or Shanxi – burning affects the lives of all three billion rural inhabitants. If we add urban areas surrounded by burning fields, we might add another 500 million. This is more than one-half the world’s population.

Crop waste fires burning across northern, central and southern China with smoke plumes running east.

Is Small-Scale Biochar a Realistic Answer to Such a Big Problem?

Not all developing world farms are small and in places even small farms permit crop waste collection. Where there are large landowners, tractors plow waste back into fields. Elsewhere state programs permit large-scale collection and processing for biochar or power.

One option is distributed biochar production. Prof. Pan Genxing at Nanjing Agricultural University, for example, has developed a system of local crop waste collection depots that serve pyrolyzers that operate year round. His system permits farmers to replant fields within days, minimizes collection, keeps capital equipment operating at capacity, provides farmers local biochar inputs and eliminates burning. On the great rice growing plains of China, Pan's system cuts the amount and cost of synthetic fertilizer farmers require and binds up the heavy metals that contaminate many Chinese fields.

Chinese biochar-amino acid-microbe fertilizer mixer, the end point of large-scale distributed biochar production. The machine can produce 20 tonnes per year.

A second option is distributed biomass power. Locating small (1 MW) biomass power plants in areas with easily collected crop waste can provide power where needed and slash grid costs. Plants do not produce biochar, but eliminate burning and earn farmers new income. The short fuel collection radius minimizes the carbon footprint of transportation. Small size permits the use of gasifier technology that requires no local water while clean burning 17,000 tonnes of waste annually. A string of strategically placed plants could save billions of dollars and avert the environmental damage of grid construction.

So Why Care about Small-Scale Biochar?

Because neither big biochar nor biomass will go where most burning occurs.

The 475 million households farming two ha or less will never own a tractor. Their fields are too small, too steep, too rocky for anyone to want the little biomass they generate.

No one wants to harvest the corn stalk up here. Much easier to burn.

Collectively, however, small farmers produce and burn a lot of waste. (Data. FAOSTAT)

	Corn	Rice	Soy	Wheat	Total
Total	1,470,771,897	704,785,717	199,829,165	318,863,682	2,694,250,461
10.00%	147,077,190	70,478,572	19,982,917	31,886,368	269,425,046
25.00%	367,692,974	176,196,429	49,957,291	79,715,921	673,562,615

How much crop waste do they generate? Starting with conservative assumptions:

- Real average farm size is just one ha.
- Only one-half of all small farmers grow a big four food crop.
- This one-half of farmers divide growing these crops equally among themselves; one-quarter grow corn, one-quarter rice, etc.
- This gives us 475 million ha, of which one-half (237.5 million ha) is used for big four crops and this is divided into four equal portions of 59 million ha.

Even with these very stringent assumptions, small farmers are perfectly capable of accounting for more than 100% of total burning (294 million tonnes v. 270 and 737 v. 674). (See Table 1. Data, FAOSTAT)

59,000,000	Corn	Rice	Soy	Wheat	Total
Tonnes/Ha	12.71	7.14	3.10	5.40	
Waste/Tonne	2.70	1:1	1:1	1:1	
Total Waste	2,024,337,739	421,278,229	182,981,977	318,340,611	2,946,938,556
10%	202,433,774	42,127,823	18,298,198	31,834,061	**294,693,856**
25%	506,084,435	105,319,557	45,745,494	79,585,153	**736,734,639**

Small farmers burn lots of biomass and will burn until offered a better alternative.

Small-scale biochar is that better alternative and it benefits everyone.

How Big Are Those Benefits?

To put eCO2 emissions from crop burning and CO2 sequestration in context (see Part 2 for the Emission Factors and data sources that generate these figures):

- Burning 270 million tonnes of crop waste emits 289 million tonnes of eCO2. In 2015, Poland emitted 295 million tonnes.
- Burning 674 million tonnes of crop waste emits 772 million tonnes of eCO2. In 2015, Germany emitted 778 million tonnes.
- Biocharring 270 million tonnes of crop waste sequesters 810 million tonnes of CO2 ***annually***. This one third as much CO2 as India, the world's third largest emitter emitted.

- Biocharring 674 million tonnes of crop waste sequesters 2 billion tonnes of CO_2 ***annually***. This is one third as much CO_2 as emitted by the entire European Union in 2015.

The rural income impact of biochar production is also big.[1] At a field price of $0.067/kg,

- 270 million tonnes of crop waste will produce 68 million tonnes of biochar worth $4.6 million.[2]
- 674 million tonnes of crop waste will produce 169 million tonnes of biochar worth $11.3 million.

The Benefits of Biochar Plus

Biochar is great stuff. Making it alleviates big problems and using it alleviates more. This series, however, has made the case for small-scale biochar for a reason. Farmers worldwide can use whatever biomass they have and homemade technology to make workable biochar. But not all biochar technologies can solve the big climate, environment, health and rural poverty problems addressed here.

Large-scale pyrolyzers at timber mills and furniture factories avert eCO_2, smog precursor and $PM_{2.5}$ emissions that would come from waste wood burning. They cannot address the huge quantity of widely dispersed, otherwise worthless crop waste in poor farmers' fields. Only small-scale biochar made by small farmers can do this.

Making biochar from any waste biomass is good. To address crop waste burning, however, biochar must go where the problem starts: in the fields of individual, small farmers at the rural fringe of the developing world. This means small-scale biochar because there is no room for scale out where the fires – and need – are.

[1] Specific impact depends on the number of participating households. Warm Heart experience suggests that, only 1 in 25 families will make biochar. Of 2,259 households where Warm Heart first tested the model, 100 participated. These families averaged $100 each, equivalent to household income for one month.

[2] Assumes 25% conversion rate in TLUDs.