2016

An Unconventional Way

Of Raising Pigs, Chickens and Cows

Four levels of waste transformation are adapted and applied to the raising of pigs, chickens and cows. Farmers ferment waste and use it as feed (Level 1). They feed fecal matter to the larvae of the black soldier fly, they feed larval residue to red worms, and they fertilize their crops primarily with vermicompost (Level 2). They house pigs, chickens and cows on a soft mesophilic bedding (Level 3) sprayed each day with probiotic liquids. They add biochar from top-lit, updraft gasifiers to the fermented feed and to the bedding, and they use syngas for household cooking (Level 4). The bedding has no odor. There are no flies. At no point in their lives are antibiotics or any other pharmaceuticals administered to pigs, chickens and cows raised in this unconventional way. Just about all of the behavioral and physiological needs of animals and poultry are met. Instead of inhumane confinement or free-range, we propose a third way: confinement in a clean, spacious and odorless setting that accords comfort and dignity to animals. High levels of productivity are achieved, not by means by over-crowding, antibiotics, growth hormones or chemical fertilizers - but by lining up multiple, interdependent waste transformation cycles that all reduce cost and generate income. These waste transformation technologies can even be extended to include the recycling of bone, human waste and biodegradable household waste. Through the wise and efficient transformation of waste, farmers buy nothing from feed, fertilizer, pharmaceutical, and fuel companies. Strong and self-reliant, farmers no longer depend on the fragile infrastructure of global trade. Large international corporations that enslave small farmers through the sale of unsustainable inputs are shut out, along with traders peddling cheap subsidized products that devastate local economies. In this way a lot more jobs are created and a lot more money is made at the local level. The social upheaval caused by the migration of young people to large cities is eliminated. Poor people, especially poor women, are empowered as never before. Food production increases. Food security, along with national security, is enhanced. Trade figures improve. Human health is not endangered. The environment does not suffer. And neither do pigs, chickens and cows.

EPWT

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Empowering the Poor through Waste Transformation

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FOUR TYPES OF WASTE AND FOUR TYPES OF WASTE TRANSFORMATION

One sees in Vietnam two things in great abundance: a lot of waste and a lot of poverty. A while back we asked a simple question: could the transformation of waste be the means that would enable poor people to acquire substantial wealth? We looked at every possible form of biodegradable waste: agricultural waste, forestry waste, fish by-products, fish excreta, crustacean waste, slaughterhouse waste, hatchery waste, milk by-products, food waste, household waste, bone waste, and even human waste. Nowhere could we find anything that could not be transformed into products of great value.

But to get the highest economic return and the greatest environmental benefit in the transformation of waste, the right technologies are needed. If technologies are expensive and sophisticated, poor people will not be able to afford them or acquire the skill to operate them. Each technology has to be simple and low-cost, yet when brought together and properly integrated, something happens that goes far beyond any one technology viewed in isolation. Many natural cycles of waste transformation are needed, all deeply interconnected, all adding value to one another, all endlessly renewing themselves in a self-sustaining manner. Here not a gram of waste is wasted, and waste, in all of its many forms, can become the greatest resource that a poor man or poor woman in Vietnam could ever possess.

Most people view biodegradable solid waste as messy- as an utter nuisance - as a total loss - something to get rid of or flush away as quickly as possible. We contend, however, that all of it, every bit of it, if correctly transformed, offers substantial wealth. But before we can tap into the bounty that waste has to offer, there's a waste hierarchy that we should recognize and respect.

Biodegradable solid waste can be situated into four different types in descending order of nutrient content. The first two types of waste are putrescent, and the last two types are non-putrescent.

	Types of Waste	**Methods of Transformation**	**Products**
1.	high-grade putrescent	fermentation	feed
2.	low-grade putrescent	larvae and red worm bioconversion	larvae, worms, vermicompost
3.	high-grade non-putrescent	composting	compost
4.	low-grade non-putrescent	gasification	syngas and biochar

Type 1 waste (e.g. fresh food and fish by-products) contains a lot of nutrients. Ideally this waste should be transformed into feed. Lactic acid fermentation stands out as the preferred way to transform waste into feed. Type 2 waste (e.g. fresh pig, chicken and cows feces) contains less nutrients. Generally there's no better and no quicker way to transform this type of waste than through the combined action of larvae and worms. Type 3 waste (e.g. fresh coffee prunings and water hyacinth) composts quite well through the combined action of bacteria, fungi, protozoa, actinomycetes, rotifers and so forth. Type 4 waste (e.g. rice hulls and coffee husks) consist of low-grade ligno-cellulosic biomass, and in many instances, it constitutes an ideal fuel for gasifiers.

High-grade putrescent waste should not be fed to larvae and worms, unless it has spoiled and can no longer be preserved as feed. Minimizing the number of trophic levels involved in waste transformation normally leads to greater efficiency. Low-grade putrescent waste that can be fed to larvae and worms should not be composted or converted into biogas. Larvae, worms and vermicompost are far more valuable than either compost or biogas. Green waste that can be easily composted might not gasify very well. And low-grade, ligno-cellulosic biomass should never be uselessly dumped or burned, especially when it can be easily and inexpensively transformed into syngas and biochar.

There are some forms of biomass that defy easy categorization. Straw, for example, can be processed by fungi into food. If properly amended, it can serve as feed. If its C:N ratio is adjusted, it can be composted. When cut to a short length, it makes excellent bedding for poultry and animals. And when cut to a short length or formed into pellets, it can be gasified. The malleability and sheer abundance of straw make it amenable to multiple methods of transformation.

If we want the highest economic return and the greatest environmental benefit in transforming waste, and if we want to eliminate the twin scourge of poverty and pollution, we should be prepared to employ a variety of waste transformation methods. Our greatest temptation is to focus on one solution that overrides all else.

In this paper we will examine how the wise and efficient transformation of waste impacts the raising of pigs, chickens and cows. We begin with pigs and the transformation of pig waste.

SHOULD PIG WASTE BE ROUTED TO BIODIGESTERS?

Letting raw pig waste flow into lagoons, streams and rivers is an absolute disaster (8 Disgusting Facts about Hog Poop). So beginning back in 1992, tens of thousands of anaerobic digesters were installed over the years on pig farms throughout Vietnam. Here the urine and feces of the pig are flushed off concrete floors and routed to biodigesters that produce methane. But is this the best way to dispose of pig waste?

The first thing that stands out is the inefficiency of the biodigester. Over half of the nutrients excreted by the pig are in the form of urine. Generally the urine of the pig contains over three times more nitrogen than the feces of the pig, as explained in Understanding and Applying Nutrition Concepts. When urine enters a biodigester, the nitrogen it contains is not used by the microbes within the process due to the fact that the C:N ratio of pig feces is generally well below 30:1.

A biodigester only transforms into methane the putrescent volatile solids within pig feces. Fresh pig feces contains less than 6% volatile solids (Biogas as fuel). If these solids are mixed with flush water, the amount of volatile solids entering the biodigester often situates at less than a third of a per cent. Then only 40 to 45% of the volatile solids entering the biodigester are actually converted into methane and carbon dioxide (CH_4 AND N_2O EMISSIONS FROM WASTE WATER HANDLING). Furthermore, there are fugitive emissions - leaks in the system- which range from 10 to 15% (Quantifying Fugitive Methane Emissions from Biodigesters). Finally the percentage of carbon dioxide within the biogas that makes it to a stove ranges from 30% and 50% (Project and leakage emissions from anaerobic digesters).

So the amount of material entering a biodigester that gets transformed into methane situates at few hundred parts per million. A biodigester transforms just about none of the urine and only a small fraction of the feces into methane.

It's not surprising that a biodigester leaves behind a lot of sludge and effluent. Biodigester sludge is not always cleaned out in a proper and timely manner. Before it can be incorporated into the soil, raw sludge should be composted or vermicomposted. Many farmers in Vietnam do not bother. They dump it. The effluent from the biodigester, rich in NPK, can be used to fertilize crops, it can be immersed in biochar, it can be processed in duckweed ponds, and so forth. Many farmers do not bother to do any of these things. They let it flow into nearby streams and rivers. Small biodigesters often operate at mesophilic temperatures, and via the sludge and effluent they produce, a variety of antibiotic resistant pathogens make it into the environment.

When farmers make an attempt to apply biodigester slurry to land as fertilizer, they often do not store it. Slurry should not be continuously applied to crops. It has to be stored and applied in a timely manner according to crop needs. Fertilization at the wrong time leads to significant waste and inefficiency. Even when farmers attempt to store biodigester slurry, they do not store it properly. Storage vessels often leak.

During anaerobic digestion, a fair amount of organic N and P gets mineralized, and this amplifies problems associated with nutrient escape. During the storage of slurry, and especially during land application, there can be substantial losses of NH_3 gas. Afterwards there can be losses to surface and ground water through nitrate leaching. Then there can be losses to the atmosphere in the form of nitrous oxide. Furthermore, if the application of biodigester slurry to the land is not "carefully managed and controlled," mineralized phosphorous is easily lost to the soil as run-off (Nutrient Value of Digestate from Farm-Based Biogas Plants in Scotland). Consequently a lot of plant nutrients from biodigester slurry never make it into the crops they are meant to fertilize. This leads to eutrophication and algal blooms in nearby waterways.

A biodigester is always producing gas, and this necessitates the construction of a gas storage vessel. To minimize distribution losses, storage vessels are generally located in proximity to kitchens, sometimes even within kitchens, as shown in this video. If ever they should leak, there is the danger of explosion, fire, asphyxiation and hydrogen sulfide poisoning (Anaerobic Digesters and Biogas Safety). Piping methane from the biodigester to the storage vessel and from the storage vessel to the stove is risky. Rats at times gnaw holes in storage vessels and in plastic gas pipes.

Recent experiments conducted in Vietnam and Laos show the effectiveness of rice hull biochar in cleaning up biodigester effluent. But to produce biochar, gasifiers are needed, and the primary product of gasifiers in terms of economic value is not biochar but syngas (CO and H_2). Syngas should not be wasted or flared, but utilized as fuel in the production of high-grade heat. Since syngas can be used by pig farmers for household cooking, it undermines the need for biogas.

Instead of utilizing pig feces to make fuel, we suggest that the farmer use low-grade, ligno-cellulosic biomass. What can be easily transformed into valuable feed and fertilizer at level 2 should not be transformed into fuel at level 4. Perhaps the greatest folly of all is the transformation of food (such as corn, cassava and palm oil) into fuel (such as ethanol and biodiesel). See End the Ethanol Rip-Off.

GASIFIERS SEAMLESSLY REPLACING BIODIGESTERS

So in the production of high-grade heat, gasifiers can seamlessly replace biodigesters. Here we are talking about top-lit, updraft gasifiers constructed out of bright-annealed 304 stainless steel. They can easily fulfill the cooking needs of the average Vietnamese household. Set within beautiful enclosures, they rival in appearance modern kitchen appliances. See Empowering the Poor through Small-scale Gasification.

In this type of gasifier, hot syngas is burned at the top of the reactor. It's not cooled down and distributed to remote burners through pipes that might leak. The syngas produced in these gasifiers

is not stored. It's produced only as needed. In less than a minute after this type of gasifier is lit, syngas is in full production (How to Operate the 150 Gasifier). Without a pot, the flame looks likes like this (video). With a pot, the flame looks like this (video).

This type of gasifier can be used to dry many agricultural products, such as paddy rice, coffee cherries and cassava (see jpegs 001, 002, 003, 004, 005, 006, 007, 008, 009, 010, 011 and 012 as well as drawings 004, 009 and 011). It can also be situated under a rotating drum to roast coffee, cacao and soybeans (see this instructional video). This roaster (including gasifier) costs about 25 times less than a conventional roaster, and the cost in energy to power it is about 1,000 times less.

In the transformation of low-grade biomass by means of gasification, the efficiency of the process is quite high. Most of the volatile matter and even some of the moisture within the biomass are converted into syngas. This gas contains little carbon dioxide. Also, just about all of the fixed carbon and ash within the biomass are transformed into biochar.

At the same time, the farmer plays an active role in recycling low-grade biomass that all too often is dumped in fields and rivers, or uselessly burned. The useless burning of rice hulls and rice straw in the lowlands, as well as the useless burning of pine forest debris in the highlands, represents a colossal environmental problem in Vietnam. At times entire villages and cities are completely enveloped in soot and smoke. This is particularly sad, since one ton of rice hulls or rice straw has a combined value in syngas and biochar of over $300 US. Rice hulls often have a greater value than the paddy rice from which they are derived.

Another big drawback in the use of biodigesters is the amount of water needed to flush waste. Farmers in Lam Dong province use on average about 125 liters of flush water per pig per day. This adds up to about 15 tons of water over the lifetime of a pig. In the US this figure is more than the double. Pumping requires electricity, and it often makes demands on limited fresh water resources. Fresh water shortages already threaten sustainable development in Vietnam (Fresh water shortage threatens sustainable development and Water Crisis Vietnam and River Salinity from Sea). So in flushing waste to biodigester, farmers do not always pump fresh water. At times they recirculate dirty water from lagoons. Such water serves as a powerful vector for the transmission of disease.

THE DISASTEROUS IMPACT OF CONCRETE ON RAPIDLY GROWING LEGS

But none of the above issues related to the use of biodigesters grabs our attention like the hard concrete floor needed for flushing to take place.

Concrete floors have a terrible impact on the muscles, tendons, cartilage and bones of the pig (Leg Weakness – Osteochondrosis). When pressure and shear stresses are applied to the rapidly growing legs of pigs, some awful things happen. Cartilage gets damaged and is replaced by fibrous tissue. This in turns produces shortening and bending of bones. Cartilage splits and form fissures in pigs as young as two months of age. Fractures might occur in the knee and elbow joints. Hip, knee and elbow joints often become inflamed. Knees might bend inwards, and front feet might rotate or twist. In most cases healthy angulation of the leg bones disappears, and legs straighten out in an abnormal way. Pigs tend to walk on their front toes in a stiff goose-stepping fashion. Pigs often suffer infections such as bush foot and foot rot. Many of these problems become irreversible at a young age.

High levels of vitamin A, high levels of lysine, high stocking densities and the use of growth hormones and leanness drugs – all aggravate the situation. Pigs are under constant stress and pain. *No amount of biogas could ever justify the stress, pain and filth under which pigs are forced to live.* When pigs are brought to slaughter after having spent four months on concrete floors, they have great difficulty walking. Some are even lame. "Lameness is the 3rd most common cause for treatment with antibiotics in weaner and finishing pigs" (Lameness in Pigs). Pigs should never – never be housed on concrete floors. This practice is cruel, savage and inhumane.

"THE MOST FRIGHTENING EPIDEMIC SINCE AIDS"

The terrible conditions under which pigs are raised necessitate the constant use of antibiotics. As Maryn McKenna explains, antibiotics are "the only way to keep livestock healthy long enough to efficiently put on weight" (Superbug). Pigs are regularly injected with antibiotics, and antibiotics are added to their feed. It's estimated that 80% of the antibiotics purchased in the US are used on farm animals" (Concerns grow over farm drugs used like 'sweets'). This abuse of antibiotics is exceedingly foolhardy and dangerous. It leads to increased bacterial resistance. Antibiotics "contribute to the growing problem of bacterial infections that are resistant to treatment in people" (Antibiotics in Animals Tied to Risk of Human Infection).

Over the years the Food and Drug Administration in the US failed to put an end to antibiotic abuse (The F.D.A.'s Not-Really-Such-Good-News). The CDC estimates that about two million Americans fall ill each year from antibiotic-resistant infections, and another 23,000 Americans die (The Peril of Antibiotic Use on Farms and A New Attack on Antibiotic Resistance). The CDC cautions that these "estimates are based on conservative assumptions and are likely minimum estimates." In India more than 58,000 infants died in 2014 as a result of antibiotic-resistant infections ('Superbugs' Kill India's Babies and Pose an Overseas Threat).

A recent study reveals that those living near large pig farms have an increased risk of being infected with an antibiotic-resistant staph called MRSA (Almost Three Times the Risk of Carrying MRSA from Living Near a Mega-Farm). Also, much of the pork and poultry products sold in America are contaminated with MRSA. "Nearly half of the meat and poultry samples -- 47 percent -- were contaminated with S. aureus, and more than half of those bacteria -- 52 percent -- were resistant to at least three classes of antibiotics" (US meat and poultry is widely contaminated with drug-resistant Staph bacteria, study finds). In Vietnam MRSA spreads from pig farms to humans, from open-air markets to humans, from humans to humans, and from humans back to pigs - in a cycle of death and disease that's totally out of control.

The incidence of MRSA in some Asian hospitals reaches as high as 80% (Spread of methicillin-resistant Staphylococcus aureus between the community and the hospitals in Asian countries). At 74.1%, Vietnam has one of the highest MRSA rates in Asia. As Maryn McKenna sums it up, "Medicine disregarded it. Antibiotics can't control it. MRSA – drug resistant staph – may be the most frightening epidemic since AIDS" (Superbug - The Fatal Menace of MRSA). MRSA now kills more people in the US than AIDS (More U.S. Deaths From MRSA Than AIDS). If you want to see just how frightening MRSA looks like on humans, pigs, poultry and pets, take a look at these gruesome images.

When antibiotics are administered to humans, "good bacteria that protect against infection are destroyed for several months," and Clostridium difficile easily takes over (Antibiotic Resistant Threats in the United States, 2013). C. difficile is the leading cause of infectious diarrhea in hospitalized humans. C. difficile causes severe, and at times, fatal diarrhea, as well as colitis that might call for the removal of the colon. C. difficile ranks alongside MRSA as a grave threat in hospitals and nursing homes around the world. According to the CDC, "almost 250,000 people each year require hospital care for C. difficile infections. In most of these infections, the use of antibiotics was a major contributing factor leading to the illness. At least 14,000 people die each year in the United States from C. difficile infections."

There's no doubt that C. difficile is transmitted from pigs to humans (Bacteria C. difficile transferable from pigs to humans). Transmission from humans to animals may also occur. "Human and pig strains of C. difficile are genetically identical in Europe confirming that a zoonosis exists" (Clostridium difficile infection: the next big thing!). Other zoonotic pathogens associated with swine can be found at Potential Zoonoses Associated with Swine.

Under the heading of "Current Antibiotic Resistant Threats," the CDC lists three microorganisms with a threat level of ***Urgent***. C. difficile stands at the top of this list. Under a threat level of ***Serious***, the CDC lists another 12 microorganisms, one of which is MRSA. Under a threat level of ***Concerning***, another three microorganisms are listed. Estimates of the total economic cost of antibiotic resistance to the US economy "have ranged as high as $20 billion in excess direct healthcare costs, with additional costs to society for lost productivity as high as $35 billion a year (2008 dollars)."

Antibiotic resistance occurs as part of natural evolutionary processes, and it's impossible to stop. The CDC shows an interesting timeline graph of key antibiotic resistant events. As soon as a new antibiotic is introduced, bacterial resistance kicks in. "During the last 70 years, however, bacteria have shown the ability to become resistant to every antibiotic that has been developed. And the more antibiotics are used, the more quickly bacteria develop resistance." The rate at which new antibiotics are being developed and approved "has steadily decreased in the past few decades, leaving fewer options to treat resistant bacteria." In fact, "no new class of antibiotics has been discovered since 1987."

Since the need for new antibiotics is so urgent and since doctors are becoming so frantic and desperate in treating antibiotic resistant infections, some want to waive the usual drug testing protocols in favor of directly testing new antibiotics on very sick patients (Pressure Grows to Create Drugs for 'Superbugs'). But such fast-tracking and rule-bending are just buying time. It does not address the core issue: the use of antibiotics on conventional factory farms. If the use of antibiotics on farms continues, antibiotics will soon become useless in combating human disease (When Bacteria Can No Longer be Stopped).

The World Health Organization issued a report that uses adjectives such as "apocalyptic" and "alarming" in its appraisal of the crisis we face (Antimicrobial resistance: global report on surveillance 2014):

A post-antibiotic era – in which common infections and minor injuries can kill – far from being an apocalyptic fantasy, is instead a very real possibility for the 21st Century… The report makes a clear case that resistance to common bacteria has reached alarming levels in many parts of the world and that in some settings, few, if any, of the available treatments options remain effective for common infections.

In Vietnam antibiotics are used for disease prevention and growth promotion at all levels (Antibiotic Utilization in Pig and Chicken Production: Case Study in Red River Delta). Farmers in Vietnam are allowed to inject antibiotics into sick and dying pigs, and obviously they are far from being trained in their use. Many administer antibiotics in an arbitrary, casual and unscientific manner without veterinary or state supervision and inspection. Many administer antibiotics at higher than recommended dosages, and farmers have access to antibiotics banned by Vietnamese law (Farmers advised on proper use of antibiotics in breeding). The use of antibiotics by farmers constitutes, no doubt, one of the biggest threats to human health in Vietnam.

A TOTAL BAN ON THE USE OF ANTIBIOTICS WITHIN AGRICULTURE

It's not enough to ban the use of antibiotics for growth promotion and disease prevention within the swine industry. Even in the case of a sick or unhealthy pig, antibiotics should not be used. Most pigs raised in the conventional way are not healthy. And how exactly does one go about defining a healthy or an unhealthy pig? Can we trust veterinarians to diagnose properly the condition of each pig? When veterinarians dispense antibiotics, they, like many doctors, are all too quick to do so in a careless manner. The CDC estimates that "up to 50% of all the antibiotics prescribed for people are not needed or are not optimally effective as prescribed." If doctors do such a bad job in prescribing antibiotics to humans, imagine the abuse of veterinarians in administering antibiotics to animals and poultry. Imagine further what happens when farmers are allowed to administer antibiotics. It's total madness.

The ban should also include antibiotics used in horticulture and aquaculture, as well as all types of antibiotics. We recommend that *under no circumstances should farmers or veterinarians be allowed to administer antibiotics to anything destined for human consumption.* If farmers cannot raise pigs without administering antibiotics, they should not be in the business of raising pigs. If scientists cannot come up with a set of guidelines showing farmers how to raise pigs without the use of antibiotics, they're doing bad science.

THE ORIGIN OF THE FACTORY FARM

We said that the terrible conditions under which pigs are raised necessitate the constant use of antibiotics. But if we look back on the history of the factory farm, the story is a bit more nuanced. Pagan Kennedy describes in a New York Times article (The Fat Drug) how pharmaceutical companies discovered back in the 1950's that antibiotics, aptly called the fat drug, could miraculously boost the growth of farm animals and humans. In the 1950's antibiotics were administered on a daily basis to school children in Guatemala, spastic children in Florida and several hundred US Navy recruits – and all mysteriously gained weight.

Meanwhile Jay C. Hormel got involved. “Hormel scientists cut baby piglets out of their mothers’ bellies and raised them in isolation, pumping them with food and antibiotics. And yes, this did make the pigs fatter.” A bit further we read:

By 1954, Eli Lilly & Company had created an antibiotic feed additive for farm animals, as ‘an aid to digestion.’ It was so much more than that. The drug-laced feeds allowed farmers to keep their animals indoors — because in addition to becoming meatier, the animals now could subsist in filthy conditions. The stage was set for the factory farm.”

Antibiotics made it possible for pigs to be brought indoors, raised on concrete floors under the filthiest of conditions, and to be mercilessly treated as nothing but meat machines. Antibiotics made it possible for the factory farm to exist.

It seems that we now have a better understanding of why small doses of antibiotics “promote growth.” They make subtle changes to the gut microbiome (see Can Antibiotics Make You Fat? as well as Antibiotics in early life alter the murine colonic microbiome and adiposity). Even small residues of antibiotics in meat – residues below “safe” US levels - can destroy lactic acid bacteria in normal sausage-making and allow pathogens like E. coli and Salmonella to flourish (Residual Antibiotics Disrupt Meat Fermentation and Increase Risk of Infection).

AN ALTERNATIVE TO FACTORY FARMS

In this paper we will show that it’s possible to do away with concrete floors and all of the pain and disease associated with them, that it’s possible to raise pigs indoors under clean and odorless conditions, and that it’s possible to raise pigs in a manner in which just about all of their physiological and behavioral needs are met. Finally we will show that all of the above can be accomplished without the use of antibiotics.

Instead of hard concrete floors, we propose soft bedding comprised of a combination of cut straw, rice hulls or some other form of fine, dry biomass (How to Prepare and Maintain a Bedding for Pigs). About 5% biochar by volume, together with a small amount vermicompost, is added to the bedding. We stress that the bedding should be fine. Whole straw or wood chips should not be used. We recommend that the bedding be composed of transformed waste from levels 2, 3 and 4.

But before going into more detail about the bedding, let’s first explain what happens to the feces of the pig. The urine and feces of the pig are not allowed to mix. Feces is collected off the bedding and placed in a device called a biopod. Shown in these photos (001, 002, 003) is the original round biopod invented by Paul Olivier back in the year 2000. This device is ideal for the production of black soldier fly (BSF) larvae.

THE LARVAE OF THE BLACK SOLDIER FLY

These amazing creatures are some of the most voracious eaters within the natural world (see BSF and Red Worm Bioconversion). In the transformation of fecal material, they are incredibly fast and efficient. They are reported to digest certain types of putrescent waste “more efficiently than any other known species of fly” (Biochemical characterization of digestive enzymes in the black soldier fly, Hermetia illucens).

They can effect as much as a 20-fold reduction in the weight and volume of some forms of putrescent waste in a period of less than 24 hours. In an area of one square meter, they can eat up to 40 kg of fresh pig feces per day. And for each 100 kg of pig feces, there can be as much as 20 kg of live larvae of a high protein (42%) and fat (34%) content. Nothing quite matches the speed and efficiency at which pig feces acquires value.

Here are two videos (video1 and video2) of BSF larvae in what was just a few hours earlier fresh pig feces. When larvae eat pig feces, not a drop of leachate is produced. After eating fresh pig feces, larvae leave behind a residue that is fine, dry and granular. Some coffee farmers in the highlands of Vietnam also raise pigs. Some have learned to raise BSF larvae on fresh pig feces, and they apply larval residue to their coffee plants as fertilizer. They typically feed live larvae to chickens or ducks.

When live larvae are fed to catfish, mortality rates have been noted to drop from 45% to 5%. When sold in such applications, they are valued over a $1,000 US per ton. BSF lipids are comprised of about 54% lauric acid, an acid active against lipid coated viruses (including HIV and measles), as well as Clostridium and many pathogenic protozoa (Black Soldier Fly Larvae Breakdown). "Lauric acid is the main antiviral and antibacterial substance found in human breast milk" (A Review of Monolaurin and Lauric Acid).

The monoglyceride of lauric acid, known as monolaurin, has profound antiviral and antibacterial activity. This amazing mono-ester kills several types of pathogenic bacteria that are resistant to antibiotics. Yet it does not have an adverse effect on beneficial gut bacteria. It effectively combats many gram positive bacteria as well as a long list of deadly viruses. Several lauric acid mono-ester formulations even prove to be effective against MRSA, swine flu and bird flu. "Both humans and animals can metabolize some monolaurin from lauric acid."

Hemolymph extracts from BSF larvae are proven to combat MRSA and E. coli (Isolation and Characterization of a Novel Antimicrobial Peptide from the Black Soldier Fly). BSF larvae are high in lysine, and they make an excellent feed for pigs. BSF larvae can replace dried plasma in the diet of early weaned piglets (The use of soldier fly prepupae as a replacement for blood plasma in phase 1 and 2 nursery diets).

About 67 million swine are raised in the United States. If the feces of these swine were fed to BSF larvae, "about 5,000 tons of dried prepupae meal would be produced per day (1.8 million tons per year)" (Research Summary: Black Soldier Fly Prepupae - A Compelling Alternative to Fish Meal and Fish Oil). Over 26 million swine are raised in Vietnam. If their feces were fed to BSF larvae, about 700,000 tons of larvae could be produced per year. To produce this feed, farmland is not needed. Photosynthesis is not needed. And industrial fish can be left in the sea right where they belong.

Some foolishly advocate making biodiesel from the crude fat from BSF larvae (From organic waste to biodiesel: Black soldier fly, Hermetia illucens, makes it feasible). But instead of utilizing such valuable fats to make liquid fuels, one can make methanol from syngas produced through the gasification of Type 4 waste. The methanol synthesis of syngas is a well-known technology. Methanol can be used in the place of gasoline, or it can be dehydrated into a type of diesel called dimethyl ether (DME). But as this paper comes to a close, we will call into question the wisdom of making liquid fuels even from Type 4 biomass. The demand for liquid fuels is so great that if they were generated from biomass, there would not be enough biomass needed for transformations at levels 1 through 4. We have to step outside of the realm of biomass to generate liquid fuels.

The European Commission has recently funded a project called *PROteInsect* to study the efficacy and safety of insect protein in pig and poultry feed (EU backs insect in animal feed project). Hopefully the European Commission will allow the inclusion of insects in poultry and pig diets. "Black soldier flies, common housefly larvae, silkworms and yellow mealworms were named as among the most promising species for industrial feed output in a report earlier this year by the FAO, the United Nations food agency." If insect meal replaced fish meal, the fishing of industrial fish such as anchovies and menhaden could be eliminated.

With a biopod, larvae self-harvest into a bucket without any human intervention or manipulation (see video). The relatively small size of the 4-foot biopod allows for 100% efficiency in larval crawl-off. One can easily stir the contents of a biopod, as shown in the above video. Frequent stirring dissipates heat, it enables larvae to eat in a fully three-dimensional space, and it results in a 5- to 10-fold increase in eating efficiency.

Any number of biopods can be coupled together to handle large quantities of waste. In a tropical setting, mating, egg-laying and the eating of waste can all take place in the same enclosure. Adults mate in fly screen extensions of the enclosure (see drawing). After mating, females have free access to biopods where they lay eggs. In a tropical setting, it is not necessary for humans to manipulate eggs or newly hatched larvae.

In the picture above left, we see BSF larvae grown in the Mekong on nothing other than pig feces. In the picture on the right, we see the biopods in which they were cultivated. The 4-foot biopod is fabricated in Saigon using 90% recycled plastic. The energy required to mold them is provided by gasifier heat.

THE AWESOME POWER OF WORMS

The residue of the larvae is not a waste. In fact it constitutes one of the best substrates for growing red worms. Red worms grow faster on BSF residue than on partially composted waste. BSF larvae digest fresh putrescent waste, something that red worms cannot do, and red worms digest the more recalcitrant fibrous material, something that larvae cannot do. Together they form a perfect partnership, recovering all possible nutrients.

So often in nature, larvae and worms feed together. As larvae feed on a putrescent substrate, right below them are red worms feeding off their residue. In Vietnam live red worms retail at times for over $5.00 US per kg, and their residue, vermicompost, sells at times for up to $500 US per ton.

Red worm castings or vermicompost constitutes one of the best growing mediums for plants (Worms Produce Another Kind of Gold for Growers and Earthworms – The Environmental Engineers). Vermicompost can be described as a humus-like material, containing "17-36% humic acid and 13-30% fulvic acid of the total concentration of organic matter" (Effects of Vermicomposts on Plant Growth). These two acids are quite effective in making phosphorous available to plants growing in acidic soils where phosphate ions precipitate with Al and Fe cations. Vermicompost makes nitrogen, phosphorus, potassium, calcium and magnesium readily available to plants.

Vermicompost should contain phosphate solubilizing bacteria and nitrogen fixing bacteria. If these bacteria are not present, vermicompost can be inoculated with them (Enriching vermicompost by nitrogen fixing and phosphate solubilizing bacteria). Vermicompost is rich in actinomycetes, fungi, cellulose-degrading bacteria and other beneficial microbes. These microorganisms produce important plant growth hormones and plant growth regulators. The microbes in vermicompost often out-compete plant pathogens.

Vermicompost significantly suppresses the activity of plant-parasitic nematodes, and yet at the same time, it increases the activity of beneficial nematodes that eat fungi and bacteria (Management of plant parasitic nematode populations by use of vermicomposts). Vermicompost can be mixed with biopesticides (e.g. neem oil, neem cake, extracts of custard apple leaves and garlic) to combat plant parasitic nematodes (COMBINATION OF VERMICOMPOSTS AND BIOPESTICIDES AGAINST NEMATODE [PRATYLENCHUS SP.] AND THEIR EFFECT ON GROWTH AND YIELD OF TOMATO [LYCOPERSICON ESCULENTUM]). Vermicompost decreases populations of arthropod pests such as aphids, mealy bugs and mites (Vermicompost can suppress plant pest and disease attacks).

VERMICOMPOST, AM FUNGI AND BIOCHAR

Vermicompost also promotes the growth of arbuscular mycorrhizal fungi (AM fungi). These fungi invade plant roots, while fanning out over a vast area of soil to transform, gather and transfer nutrients to plants. If plants cannot form associations with AM fungi, they must put additional resources into root growth at the expense of other tissues and functions. Protozoa and other microbes graze on bacteria and mineralize N. AM fungi translocate mineralized N to their host plants. But more importantly, AM fungi secrete enzymes into the soil that "dissolve nitrogen rich tissues of dead and living organisms" (Misunderstanding Soil Ecosystems), directly converting organic soil nitrogen into inorganic forms, thereby "short circuiting mineralization pathways and preventing loss of N through leaching and denitrification." Plant-fungi partnerships evolved over 400 million years, and they are the "most prevalent symbioses on earth."

AM fungi also form mutualistic associations with nitrogen fixing bacteria: the bacteria supply nitrogen to the fungi, and the fungi supply phosphorous to the bacteria. AM fungi make phosphorus available in soils where it has precipitated into unavailable forms (Arbuscular mycorrhizal fungi enhance aluminium resistance of broomsedge). AM fungi funnel up to 80% of the phosphorus and nitrogen needed by many plants. They transport zinc and other trace nutrients to plants. They hold and transport soil water to their mutualistic partners.

The cell walls of AM fungi are 60% chitin, a carbon-rich polymer that is highly resistant to decay. AM fungi secrete carbon-rich glomalin into the soil, a glycoprotein which is also highly resistant to decay (Glomalin: Hiding Place for a Third of the World's Stored Soil Carbon). Some say that glomalin alone constitutes up to 60% of carbon in undisturbed soils. Glomalin gives tilth to the soil and takes 7 to 42 years for it to degrade (Glomalin). Therefore one of the best ways to sequester carbon dioxide and fight climate change is to promote the growth of AM fungi.

Mycorrhizal hyphae often form a protective barrier around plant roots, preventing the intrusion of nematodes. In some cases nematodes are glued to hyphal threads and die (Plant Health Care information sheet). Elsewhere we see that AM fungi in certain cases are crucial in the control of root-feeding nematodes (Mechanism of control of root-feeding nematodes by mycorrhizal fungi in the dune grass Ammophila arenaria). When plants are under attack by herbivores, nematodes and fungal pathogens, AM fungi significantly enhance plant growth performance (Meta-Analysis of Interactions between Arbuscular Mycorrhizal Fungi and Biotic Stressors of Plants). AM fungi increase root resistance to many disease-causing pathogens.

AM fungi grow exceptionally well in the presence of biochar (Mycorrhizal responses to biochar in soil –concepts and mechanisms). It was found in Japan that when one kilogram of biochar was added per square meter of volcanic ash soil, "alfalfa associations with AM fungi increased by 40-80%." (Inoculation with arbuscular mycorrhizal fungi: the status quo in Japan and the future prospects). A soil rich in carbon and biochar, a soil rich in AM fungi with its associated chitin and glomalin, is one of the best thing we've got to sequester carbon and fight climate change. Now back to the bedding.

HAPPY AND HEALTHY PIGS

Urine drains into the dry bedding and is absorbed by it. The bedding and pigs are sprayed each day with lactic acid bacteria and other effective microorganisms (EM) that vigorously compete with and eliminate pathogens (Effective Microorganisms). A probiotic spray is much more effective in destroying pathogenic bacteria, viruses and fungi than conventional cleaning and disinfectant agents, as we will soon explain.

Pigs love to play and root within the bedding (video and video). The bedding also functions as a soft cushion for pigs. Pigs have no problem running and sprinting on bedding, as clearly seen in the second video. Balls and other toys should be made available to pigs on bedding to keep them active, entertained and fit. For example, if given a rope with knotted ends, young pigs play tug-of-war. Toys reduce the incidence of tail- and ear-biting right down to zero. If pigs are not in pain and under stress, and if they are kept entertained and happy, they do not engage in anti-social behavior.

Larvae and red worms can be released into the bedding while pigs are sleeping. The larvae and worms go down into the bedding and hide. Pigs have an incredible sense of smell, much better than that of dogs, and when they wake up, they thoroughly enjoy rooting through the bedding in search of larvae and red worms. Larvae and worms are a true delicacy for pigs.

The behavior of pigs in rooting through the bedding in search of larvae and worms closely resembles that of pigs in the wild. Wild pigs spend about half of their time rooting through the forest floor in search of larvae, worms, grubs, roots, tubers and so forth. If pigs cannot exhibit behavior such as this, "they tend to develop abnormal behavior such as biting other pigs" (Hogs).

A great idea proposed by Dr. Thomas R. Preston is to make fresh, unpeeled, hand-chopped sugarcane billets available to pigs on bedding. It appears that the best billet length is about 3 cm (Growth performance of pigs fed hand-chopped sugar cane stalks). The extraction rate of juice by pigs is quite high - 43% as compared to 49% obtained by a crusher (Utilization of sugar cane stalks and water spinach for fattening pigs). No expensive juice extraction equipment is needed. Pigs greatly enjoy this sweet delight. Any residual bagasse left behind by the pigs becomes part of the bedding. Flushing uneaten bagasse off concrete floors to biodigesters, Dr. Preston notes, has always been problematic.

Of course, one must never feed pigs fresh cane sprayed with glyphosate. According to Dr. Preston, when sows in Colombia were fed cane sprayed with glyphosate, they all gave birth to dead piglets.

In the picture on the right, we see the collection of pig feces with a dustpan and small spade. On a small pig farm, we recommend that this collection take place twice a day. The entire procedure within a pen takes less than five minutes. No more time is spent in collecting feces off bedding than in the frequent and repeated flushing of waste off concrete floors.

Fresh pig feces is far too valuable to let compost within the bedding. In larvae, red worms and biochar-rich vermicompost, pig feces is worth at least $500 US per ton. Since fecal matter does not remain on the bedding, the bedding does not heat up through mesophilic or thermophilic activity, as often happens in deep bedding systems. What we are proposing here is not deep bedding.

Filth-bearing flies are always attracted to fresh feces. But if fecal matter is removed twice daily, there are virtually no flies within the pen. Pigs at times will eat their feces. But by removing feces twice daily, we eliminate this highly undesirable activity.

Healthy pigs not suffering from diarrhea tend to defecate away from other pigs and away from their feed (Pig Production: Biological Principle and Applications). Their feces is easy to collect: they defecate in a limited area, and their feces is not a liquid but a firm solid. It is important for many reasons that pigs have little contact with fecal material. Their skin should always stay bright, shiny and clean.

CONCRETE FLOORS, BIOAEROSOLS AND BIOFILM

But pigs raised in the conventional way often suffer from diarrhea, and at times they defecate uncontrollably while eating. This puts watery fecal material just about everywhere on the concrete floor of the pen. Flushing the concrete floor of a pig pen with water does virtually nothing to control pathogens. In fact flushing aerosolizes ammonia and fecal matter, and aerosolized waste might contain a large number of bacterial and viral pathogens (Flu Farms). Biofilm inevitably covers the surface of the concrete floor, and no amount of flushing can remove this sticky slime. "About 99% of the world's population of bacteria occur in the form of a biofilm" (AN INSIGHT INTO BIOFILM ECOLOGY AND ITS APPLIED ASPECTS).

MRSA, Salmonella, E. coli, Clostridium and many other pathogenic bacteria thrive within biofilm (Prevalence of Biofilm Formation Among Methicillin Resistance Staphylococcus aureus Isolated From Nasal Carriers and Salmonella Biofilms Extremely Resistant to Disinfectants and Salmonella Biofilm – A Sticky, Dangerous Problem and Role of bacterial cell surface structures in Escherichia coli biofilm formation). Bacteria within biofilms at times can be a thousand times more resistant to antibiotics than unattached bacteria (Antibiotic resistance of bacteria in biofilms). After only seven days of biofilm growth on a new concrete slab, it's virtually impossible to remove biofilm even by means of intense scrubbing with disinfectants. The concrete floor of the pig pen becomes a perfect breeding ground for antibiotic-resistant bacteria.

Wherever pigs are raised on concrete floors as in large industrial piggeries, we can expect to see high rates of MRSA infection. In the USA, the rate of MRSA carriage among pigs is 49%, and in Holland, the rate is 39% (An Investigation of the Carriage Rate of Methicillin-Resistant Staphylococcus aureus in Pigs in the Western Province of Vietnam). However pigs raised on small farms in Vietnam show a MRSA carriage rate of only 3.63%. If pigs are raised in the manner suggested in this paper, the MRSA rate should be close to zero.

When pigs lie down to rest or sleep in a conventional pig pen, they inevitably come into contact with fecal and urine residue as well as the biofilm that covers the concrete floor. The skin of the pig is anything but bright, shiny and clean. Biofilm loaded with pathogens also covers the hair and skin of the pig. Cuts and bruises from anti-social behavior become easily infected. Skin diseases, rashes and concrete-induced sores are commonplace. One often sees hundreds (sometimes thousands) of filth-bearing flies on the pigs and throughout the pen. Pigs are continually twitching due to the annoyance and discomfort caused by flies. They scratch against the filthy biofilm-covered floor and walls of the pen. Pathogens thrive within such a filthy setting.

One might be surprised to find out that some viruses also form biofilms (Can viruses form biofilms?). "We propose that, similar to bacterial biofilms, viral biofilms could represent 'viral communities' with enhanced infectious capacity and improved spread compared with 'free' viral particles, and might constitute a key reservoir for chronic infections."

THE POWER OF PROBIOTIC CLEANING

Conventional anti-infection and anti-microbial agents are becoming increasingly ineffective as pathogens adapt and develop resistance. Therefore many hospitals are turning to probiotics to fight pathogens (How Does Probiotic Cleaning Work). Probiotic cleaning is particularly effective in destroying biofilm and in preventing biofilm formation. "A new study has found that probiotic cleaning agents can reduce bad bacteria by 1,000 fold compared with standard cleaning techniques" (Probiotics could be used to clean NHS hospitals).

Studies were carried out at the Lokeren General Hospital in Belgium, at the Jewish Home and Hospital in Miami, at St. Anne de Ferrara Hospital in Italy, at the Shriners Hospital for Children in Tampa, at the Midland Medical Clinic in Fort Lauderdale, at the universities of Liverpool and Ulster, and at the Medical Institute of Ostrava. In all of these studies, through the power of probiotics, pathogens were reduced to very low levels (A New Paradigm of Cleaning for Healthcare). We contend that spraying pig bedding with probiotics is pretty much the same as spraying a hospital toilet with probiotics. A lot more on hospital toilets toward the end of this paper.

Instead of using soaps, shampoos and deodorants, some people have discovered the power of probiotic sprays (My No-Soap, No-Shampoo, Bacteria-Rich Hygiene Experiment). Since probiotics work equally well for both humans and pigs, it's now possible that pig hygiene can be elevated to a status that matches or even surpasses that of ordinary human hygiene. Living in harmony with a stable and healthy microbiome is a far more intelligent strategy than trying to kill microbes with toxic chemicals.

FINE BIOMASS BEDDING WITH NO AMMONIA EMISSIONS

We recommend that the surface area of bedding allotted per finisher pig be at least two square meters and that the bedding have a depth of about two feet or 60 cm. Therefore the volume of bedding per pig is about 1.2 m^3, and the weight of bedding per pig is about 120 kg (based on a bulk density of 100 kg/m^3). At this ratio of bedding to pig, the bedding stays dry, sanitary and odorless.

Even though pigs urinate throughout the bedding, there are no ammonia emissions. The biochar within the bedding helps in preventing the escape of ammonia. Also, the fact that urine and feces do not mix is a factor in reducing ammonia emissions. "Segregated management of excreta may largely prevent urinary urea from being broken down by urease that is in feces" (Management Impacts on Ammonia Volatilization from Swine Manure).

Reducing ammonia emissions within a pig pen down to zero is quite important for the health of the pig. "At moderate levels of concentration, ammonia can irritate the eyes and respiratory tract; at high concentrations, it can cause ulceration to the eyes and severe irritation to the respiratory tract" (Ammonia Emissions and Safety). Reducing ammonia and nitrous oxide emissions down to zero also has important environmental implications. Did you ever go near a conventional pig pen with a concrete floor? Ammonia emissions are unbearable.

ZERO SMELL AND ZERO ANTIBIOTIC USE

This might be hard to believe, but in this unconventional approach, we can unequivocally say that *the bedding has zero smell.* The pig does not come into contact with dirty biofilm containing MRSA and other pathogens. The eyes and respiratory tract of the pig are not exposed to ammonia. Fly pesticides are not used, as in conventional pig pens (Flies). Skin diseases, rashes and concrete-induced sores do not appear. Most of the discomfort due to itching stops. Due to the removal of fecal material from the bedding as well as the feeding of fermented feeds, the pig is not infested with gastro-intestinal parasites. Leg weakness, foot infections and lameness are eliminated. In such an environment, there is no anti-social behavior. What does all of this mean?

At no point in their lives are antibiotics or any other pharmaceuticals ever administered to pigs raised in this unconventional way.

An unconventional farm with 30 pigs was constructed in a residential area within the city limits of Dalat, a city of 200,000 inhabitants. There were houses to the left, right and on the hill right above the pig pen. Everyone living near the pen were amazed: there were no flies, and there was absolutely no smell.

By contrast all conventional pig pens in or near the city give rise to unbearable odors that pollute the air over a radius of about a kilometer. Effluent from these pig pens pollutes ditches, streams and lakes, often carrying with it MRSA and other antibiotic-resistant pathogens. Even effluent from continuously-fed biodigesters operating at mesophilic temperatures can contain many pathogenic bacteria as well as helminth eggs and enteric viruses (MINIMIZING HUMAN PATHOGENS IN THE ANAEROBIC DIGESTION OF ANIMAL WASTE). Flies from conventional pens enter nearby houses, greatly increasing the possibility of the transmission of MRSA and other pathogens from pigs to humans (Flies and cockroaches carry antibiotic-resistant bacteria from factory farms, study finds). Pig feces and urine get aerosolized whenever concrete floors are flushed, and these bioaerosols usually contain pathogens and get carried long distances in the wind.

In Lac Duong, a small village near Dalat, another farmer set up an unconventional pig pen housing 10 pigs. The young children of this farmer frequently entered the pen to play with the pigs. Since the pigs and the pig pen were clean, the children did not get dirty or smelly while at play. It was a lot of fun both for them and for the pigs. Imagine children playing with pigs in a conventional pig pen. Totally unthinkable!

In May 2014, a virus swept through Lac Duong and the surrounding area. This virus was lethal. The mortality rate of pigs on some pig farms reached 100%. Over 500 pigs in the area died. But the pig farmer in Lac Duong raising pigs in the unconventional way did not lose a single pig.

This farmer was given a mesophilic composting bin (a device described toward the end of this paper in the section on recycling biodegradable household waste). The farmer collected pig feces each day from off the bedding and put it in the mesophilic bin. Soon after he began doing this, the bin was filled with BSF larvae. The larvae appeared naturally. No inoculation with BSF eggs or larvae took place. The farmer then noticed that local red worms appeared within the bin. They were feeding off larval residue and transforming it into vermicompost.

The farmer started feeding larvae and red worms to his chickens, and he used the vermicompost to fertilize his coffee plants. He maintains that vermicompost works a lot better than the chemical fertilizers he was previously using. Since this farmer was buying no pig feed, no chicken feed, no antibiotics and no chemical fertilizers, for the first time in his life, he was in a position to make money and rise out of poverty. Over ten pig farmers in his village approached him to learn how to raise pigs in this unconventional way. The farmer used a small gasifier for cooking and warming water, and he incorporated biochar into the fermented feed and into the pig bedding.

PEN DESIGN AND PIG BEDDING

Obviously there are many way to construct pig pens. One inexpensive way is shown in these jpegs (001, 002, 003, 004, 005, 006, 007 and 008) and in these drawings (001, 002, 003, 004, 005, 006 and 007). Three pig pens, each of about ten square meters, are housed under a single rectangular hoop house structure. One pen can serve five grow-out pigs, three gestating sows, or one farrowing sow with piglets. Standard half-bricks are oriented within the wall so as to provide ventilation. Radiant barrier sheeting can be used to block out 97% of the radiant energy emitted from the roof. The use of thatch or radiant barrier sheeting is absolutely essential. Pigs should never be housed under a hot tin roof.

When daytime temperatures are high, pigs in a wild setting tend to be crepuscular and nocturnal. A farmer can take advantage of this and avoid feeding or disturbing his pigs during the hottest time of the day. This encourages them to sleep when it’s hot, and as they sleep, fans emitting a probiotic mist can be employed periodically to keep them cool and comfortable. The happiness and comfort of the pig should be the highest priority of the farmer.

As pigs walk, run and play on the bedding, it is slowly transformed into mesophilic compost. But it's not easy to sell bedding as compost, since it's always being depleted. Some of it reduces in volume through mesophilic composting, and, of course, some adheres to the feces being removed each day. But surprisingly most of it is eaten by the pigs. It is not uncommon to see at times half of the pigs within a pen eating bedding. The fine grain size of the bedding makes it easy for pigs to eat. Residual bagasse from the feeding of cane billets is broken down by microbes within the bedding and is also eaten by the pigs.

This behavior closely resembles what happens in a wild setting: pigs consume dirt. At least once each month, dry biomass and biochar have to be added to the pen to replenish bedding. When mature pigs are brought to market and young pigs are brought into the pen, the bedding does not have to be cleaned out and replaced. It is simply sprayed with probiotics in the usual manner, and it conveniently stays in place.

So bedding in the form of bedding never leaves the pen. Urine in the form of urine never leaves the pen. Not a drop of effluent leaves the pen. Transformed bedding and urine leave the pen only as fecal solids.

Microbes in the large intestine of the pig are quite good at breaking down a wide range of non-starch polysaccharides such as cellulose, hemicellulose and pectins. When the pig eats mesophilically transformed bedding rich in fiber and nitrogen, it can actually derive nutrition from doing so. "Various studies suggest that the pig can utilize fiber for growth, and up to 30% of its maintenance energy may be derived from volatile fatty acids produced in the large intestine" (Activity of fiber-degrading microorganisms in the pig large intestine). Fibrolytic bacteria in the large intestine secrete cellulase and xylanase in both growing and adult pigs. These organisms "are similar to those in the rumen and are present at comparable numbers."

In the acidic environment of the large intestine, short-chain fatty acids "inhibit the growth of some intestinal pathogens such as Escherichia coli, Salmonella spp. and Clostridium spp." (Nutritional and environmental consequences of dietary fibre in pig nutrition: a review). The fermentation of fiber in the large intestine also puts a significant amount of bacterial biomass in the feces of the pig. This induces a "shift of N excretion from urine to feces." The accumulation of bacterial biomass in pig feces can subsequently be exploited by BSF larvae. Since the pH of feces is lowered in the fermentation process, less ammonia volatilizes from feces. If biochar is added to the feed of the pig, biochar plays a positive role in gut fermentation, and it also reduces the volatilization of ammonia from feces.

So biomass enriched with biochar and probiotics serves as both bedding and feed for the pig. Nutrients within the urine of the pig are mesophilically transformed within the bedding and are returned to the pig. Here is a process in which the pig is engaged in the transformation of the nutrients within its own urine. The inefficiency in the pig's transformation of fiber and urine is remedied by the combined action of larvae and red worm.

The bedding is first processed in part by mesophilic microorganisms within the pen. It then passes through the guts of pig, larva and red worm. The products of this four-fold bioconversion process are pork, BSF larvae, red worms and vermicompost. No worthless by-products are created.

When the pig eats bedding, the biochar in the fermented feed and the biochar in the bedding combine. The primary function of biochar is to create ideal conditions in which complex communities of beneficial microbes can thrive. When biochar finally makes its way into soil embedded in vermicompost, it's activated by the beneficial microbes within the gut of the red worm. If the receiving soil is healthy, the soil will contain a great deal of castings created by indigenous red worms and earthworms. If the receiving soil is healthy, extraneous and indigenous forms of vermicompost merge and form a continuum. Indigenous worms take over the process of waste transformation that started in the bedding of the pig. More on this a bit further on.

PIGGY PACKETS

The fact that pigs eat bedding greatly simplifies feeding. If bedding is sprayed each day with probiotics, and if pigs eat bedding, why not make feed available to pigs on bedding? Troughs are relatively expensive. They are typically made out of metal, polymer concrete or just concrete – all hard materials that can injure the legs, snout and teeth of the pig. The floor of the pig pen should remain free of hard objects, which all too often interfere with the running and sprinting of pigs within the pen.

Pigs do not have the best of manners while eating. They frequently dislodge from a trough a lot of feed that ends up in any event on the bedding. Spillage is inevitable. Since pigs in a natural setting do not eat out of containers, why contain their feed? Remember the larvae, red worms and fresh sugarcane billets made available to pigs on bedding. Why not extend this concept to include fermented feed?

Fermented feed can be laid down in multiple places on the bedding so as to reduce competition while feeding. Fermented pig feed can also be made available to pigs on banana leaves or wrapped in banana leaves. The farmer can make feed available according to the nutritional requirements of his pigs. For example, the farmer might add high-protein supplements to the "piggy packets" of slow-growing pigs or runts. It's even possible to ferment certain feed materials within banana leaves. On-bedding feeding should take place in a randomized manner anywhere within the pen, except, of course, in the area where pigs defecate. The farmer should be careful not to overfeed with the result that large quantities of feed remain uneaten.

Some pig farmers in Lam Dong province have already switched in part to this new way of raising pigs. They ferment all that is fed to their pigs, and they have adopted this bedding technology. Since they buy nothing from commercial feed companies, they make more money than previously. Some farmers derive substantial income simply from the sale of pig feces to coffee farmers. Hopefully they will all become producers of BSF larvae, red worms and vermicompost. We project that the revenue from the sale or use of these three items should cover a significant portion of cost of raising pigs.

RECYCLING FOOD AND CRUSTACEAN WASTE

An estimated one-third of all food produced in the world is left uneaten. Most of it ends up in landfills where methane is produced "at a volume that amounts to an estimated 7 percent of the total emissions contributing to the global warming threat" Food Waste Grows With the Middle Class).

In contrast to such wastefulness, some pig farmers in Vietnam are quite resourceful in collecting food waste from restaurants and feeding it to pigs. But food waste should be boiled or fry-cooked to prevent the transmission of pathogens from humans to pigs. These two processes can be inexpensively carried out using gasifier heat.

Alternatively some food waste can be fermented: Lactic acid fermentation of Food Waste for Swine Feed and Effects of Fermented Food Waste Feeds on Pork Carcass and Meat Quality Properties and Anaerobic Stabilization of Food Wastes for the Elaboration of Feed Supplements for Swine. Some heat-treat and ferment: Manufacturing high-quality feed from food waste to create a 'loop of recycling'.

The pig does a good job of consuming otherwise inedible waste. Along with the chicken, it's one of the best means of disposing of certain types of putrescent waste such as food waste. As a recycler of food waste, a pig represents a lot more than the nutrition it provides (The Solution, the Pig).

The collection of food waste takes place within all major cities within Vietnam. In these two pictures, we see the informal collection of food waste in Hanoi. These pictures were taken at the end of Tong Duy Tan Street. Sometimes households set aside waste food and make it available each day to pig farmers.

In the processing of shrimp, crab and other crustaceans, a large part of their total mass, sometimes as much as 56%, is viewed as waste and is often dumped into the sea. It becomes a major pollutant in coastal areas (Chitin Extraction from Crustacean Shells Using Biological Methods). The shell of crustaceans is not waste. It contains valuable protein, calcium carbonate and chitin (Chitin).

There are two methods of breaking down crustacean shells: chemical and biological. The chemical method involves the use of acids such as hydrochloric acid. The use of such strong acids is expensive, it harms the physiochemical properties of the chitin, and it produces a toxic effluent. The liquor produced in the chemical processing of crustacean shells is worthless, and if not disposed of properly, it becomes a serious pollutant.

But if organic acids such as lactic acid are used in the demineralization process, cost is reduced, chitin is not degraded, and a liquid rich in protein, minerals and pigments is produced. This liquid can be used as animal feed, and if processed correctly, it is even fit for human consumption. "It is, like other commercially available protein powders, rich in glutamate, aspartate, lysine and leucine. In addition, it resembles beef protein, which is rich in phenylalanine" (Chitin production by Lactobacillus fermentation of shrimp biowaste in a drum reactor and its chemical conversion to chitosan).

In the lactic acid fermentation process of crustacean shells, chitin can be recovered as a solid and deacetylated into chitosan (Chitosan). Chitosan "has numerous applications in the pharmaceutical, textile, food and cosmetic industries, in agriculture and in waste water treatment." Biodegradable bioplastic can also be made from chitosan. "As a cheap, environmentally safe alternative to plastic, the chitosan bioplastic could be used to make trash bags, packaging, and diapers that break down in just a few weeks while releasing rich nutrients that support plant growth"(Chitosan Bioplastic). Chitosan bioplastic can be easily recycled and returned to agriculture (Chitosan Bioplastic).

But what really grabs our attention are the many uses of chitin/chitosan within agriculture, as nicely summarized in this review (Chitosan in Plant Protection):

Both chitin and chitosan have demonstrated antiviral, antibacterial, and antifungal properties, and have been explored for many agricultural uses. They have been utilized to control disease or reduce their spread, to chelate nutrient and minerals, preventing pathogens from accessing them, or to enhance plant innate defenses.

Certain forms of chitosan inhibit the growth and development of E. coli (Antibacterial activity of shrimp chitosan against Escherichia coli), Campylobacter (Antimicrobial activity of chitosan against Campylobacter spp. and other microorganisms and its mechanism of action), Salmonella (Effect of Chitosan as a Biological Sanitizer for Salmonella Typhimurium and Aerobic Gram-negative Spoilage Bacteria Present on Chicken Skin) and even MRSA (Antibacterial activity of aminoderivatized chitosans against methicillin-resistant Staphylococcus aureus and The use of quaternised chitosan-loaded PMMA to inhibit biofilm formation and downregulate the virulence-associated gene expression of antibiotic-resistant staphylococcus). Certain forms of chitosan are effective against H1N1 swine flu (Antiviral activity of silver nanoparticle/chitosan composites against H1N1 influenza A virus).

MANY THINGS TO FERMENT

Pig farmers can also be taught how to ferment many other types of waste: banana pseudostem, fresh coffee pulp, sweet potato vines, cassava pulp, tofu wake, sisal waste, fruit waste, brewery and distillery wastes, fish byproducts, fish mortalities, hatchery waste, poultry carcass waste, poultry viscera, slaughterhouse waste, co-cropped forages and so forth (The Potential Use of Tropical Silage). For step-by-step instructions on how to prepare an LAB starter culture, see Natural Farming: Lactic Acid Bacteria.

In the fermentation of vegetable waste, 5% molasses is added to the fermentation mix. In the fermentation of fish and slaughterhouse waste, 20% molasses is added to the fermentation mix. It is recommended that a small amount of biochar (less than 1% DM basis) be added to whatever is being fermented. Dr. Hien Van Le noted an increase of 10% in the growth of pigs when biochar was added to the fermentation mix.

Fermented banana pseudostem, along with biochar and other additives (see picture on the left), is quite effective in ridding young piglets of diarrhea. Banana stem is "rich in potassium and vitamin B6 just like the fruit. Vitamin B6 helps in production of hemoglobin and insulin. It improves the ability of the body to fight infection. Potassium helps in the proper functioning of muscles, including the cardiac muscles. It also helps prevent high blood pressure, and maintain fluid balance within the body" (Fibre of Health).

In India, Vietnam, Thailand and many other countries, people cook and eat the tender core of the banana stem (Can you eat Banana Trunk?). This paper explains step-by-step how banana stems are prepared in certain areas of Thailand. The author claims that the taste and texture of banana stem is comparable to that of Belgian endives.

On the feasibility of fermenting taro foliage, see Taro as a local feed resource for pigs in small scale household condition. In a more recent study, taro and banana stem (50:50 DM basis) were fermented together (Replacing rice bran by an ensiled mixture of taro (Colocasia esculenta) foliage and banana stem increases feed intake, diet digestibility and N retention in growing pigs). “The ensiled mixture of taro foliage and banana stem was more palatable than rice bran. All measures of dietary nutritional value (DM intake, apparent digestibility of DM, CP and N retention) were increased when the ensiled mixture of taro and banana stem replaced rice bran.” Banana stem contains sufficient soluble sugars so that molasses does not have to be added to the fermentation mix of taro and banana stem (Ensiled mixed foliage of taro leaves + petioles and banana pseudo-stems as replacement of rice bran for Mong Cai sows in small-holder farms in Vietnam).

ELIMINATING POST-WEANING DIARRHEA

Piglets raised in the conventional way often die of what is called post-weaning diarrhea (PWD). PWD is caused by various types of E. coli bacteria - bacteria that are becoming increasingly resistant to antibiotics. But when fermented banana stem juice is injected orally, a morbid piglet, if intervention is not too late, recovers in a matter of hours. Dr. Hien Van Le has been often called upon, once or twice each month, to administer fermented banana stem juice to dying piglets raised in the conventional way.

On the advantages of giving fermented feed or probiotics to piglets, see Lactobacillus brevis strain 1E1 administered to piglets through milk supplementation prior to weaning maintains intestinal integrity after the weaning event as well as Alternatives to antibiotic growth promoters in prevention of diarrhea in weaned piglets: a review as well as Application of EM1 (Effective Microorganisms) for Treatment of Diarrheic Disease in Piglets in Vietnam.

The pig farmer can grow duckweed, perennial peanut and other plants to ferment and feed to his pigs.

DUCKWEED

Duckweed is one of the fastest growing multi-cellular plants on earth. Under the right conditions, it can double in mass in less than 24 hours. On one hectare of pond, duckweed can yield 20 to 30 tons of dry matter per year. Its productivity per unit area is about 10 times higher than that of soya beans. It can extract up to 99% of the nitrogen and other nutrients from wastewater, and at the same time, it can obtain nitrogen through biological nitrogen-fixation (Nitrogen Fixation Associated with Duckweed Mats). If ammonia is present in water, nitrogen fixation within duckweed does not occur (the ammonia switch-off effect). Duckweed is more efficient in extracting nitrogen from wastewater than azolla. According to Paul Skillicorn, the maximum growth rate of azolla is only 30% of what duckweed can achieve (Azolla – What do we think about it?).

Duckweed contains little fiber, and its digestibility is just about 100%. Its crude protein content can reach as high as 45%. According to Dr. Bud Culley, duckweed protein closely resembles animal protein. According to Jay Cheng, "Duckweed behaves in much the same ways as soybean meal" (High-Protein Duckweed for Animal Feed). "Duckweed grown on nutrient-rich water has a high concentration of trace minerals, K and P and pigments, particularly carotene and xanthophyll, that make duckweed meal an especially valuable supplement for poultry and other animals, and it provides a rich source of vitamins A and B for humans" (Duckweed - a potential high-protein feed resource for domestic animals and fish). See also Duckweed as Edible Food as well as the website of Dr. Louis Landesman.

So duckweed makes an excellent animal and poultry feed. According to Dr. Ron Leng, "Pigs can use duckweed as a protein/energy source with slightly less efficiency than soya bean meal." The Mong Cai pigs of Vietnam are especially efficient in digesting duckweed. They eat twice the amount of duckweed compared with large white pigs, and therefore they grow faster on fresh duckweed than large white pigs (On-farm comparison of Mong Cai and Large White pigs fed ensiled cassava root, rice bran and duckweed). Gestating and lactating pigs can derive protein exclusively from duckweed (Parameters of digestion and N metabolism in Mong Cai piglets). Further on in this paper, we will show how easy it is to collect human urine and route it to duckweed ponds.

THE PERENNIAL PEANUT

With perennial peanut as a feed for sows, we definitely have a winner (Perennial Peanut: Developments in Animal Research):

Diets containing perennial peanut at 0, 40, 60, and 80% of the ration were fed to sows during gestation. Three separate parturition periods yielded similar results. Sows fed an 80% diet of perennial peanut farrowed more pigs than the other treatments and yielded an equivalent number of live weaned pigs compared to 100% corn/soybean ration. Body weight gain during gestation was greatest for sows fed 60% perennial peanut.

According to how it is managed, the perennial peanut has a crude protein content ranging from 13 to 32%, slightly higher than that of taro leaves which vary between 16 to 27%, and just about the same as water spinach which varies between 20 and 31%. Perennial peanut is a good source of vitamins for pigs (Perennial Peanut). The fermentation of perennial peanut together with banana stem makes an excellent feed for pigs.

Perennial peanut is a drought-tolerant, nitrogen-fixing ground cover that can be planted in existing orchards of all kinds (e.g. coffee, banana, mango and papaya). No land has to be set aside exclusively for its cultivation. It's cultivated in just about all cities in Vietnam as an ornamental plant and weed suppressant. "It tolerates soils with 70% or greater Al saturation" (Perennial Peanut). "It is not sensitive to low pH (4.6) coupled with high levels of soil Al" (Growth Responses of Perennial Forage Peanut and Two Barrel Medic Accessions to Soil pH and Aluminum Levels in an Andisol and an Ultisol). Once established, it never has to be replanted. The land on which it grows never has to be tilled. It eliminates soil erosion. It requires no nitrogen fertilizer, insecticides or fungicides. In fact, the rhizobia associated with the perennial peanut actually suppress many kinds of disease.

Since the perennial peanut covers the ground and chokes out weeds, coffee and other orchard farmers do not have to rely on dangerous herbicides such as Monsanto's glyphosate, the most commonly used herbicide in the world.

Glyphosate is highly toxic to pigs, chickens, cows, fish, humans, soil microbes, earthworms and just about everything else it touches (Detection of Glyphosate in Malformed Piglets). The pictures of malformed piglets shown in this paper are graphic and disturbing. "Glyphosate and its commercial herbicides severely affect embryonic and placental cells, producing mitochondrial damage, necrosis and programmed cell death with doses far below the used agricultural concentrations."

A bit further we see: "The authors gave an overview of reports of malformations in children of families living few meters from where this herbicide was sprayed. The risk of malformation in human embryos is very high when their mothers are contaminated at 2 to 8 weeks of pregnancy." Glyphosate doubles a person's risk of developing non-Hodgkin's lymphoma (The International Agency for Research on Cancer researchers found that exposure to glyphosate doubled a person's risk of developing non-Hodgkin's lymphoma).

In another paper we see that glyphosate inhibits the growth of healthy ruminal microbiota in cows and increases the growth of pathogens such as Clostridium botulinum (The Influence of Glyphosate on the Microbiota and Production of Botulinum Neurotoxin During Ruminal Fermentation and Glyphosate suppresses the antagonistic effect of Enterococcus spp. on Clostridium botulinum). The botulinum toxin is the most acutely lethal toxin known to man. A single teaspoon of this stuff can kill over a billion people. A similar effect of glyphosate has been observed in the gastrointestinal tract of chickens (Roundup Herbicide Linked To Overgrowth of Deadly Bacteria).

Glyphosate toxins from Roundup are implicated in skyrocketing rates of autism in children (MIT Scientist Exposes Consequences of Monsanto's Glyphosate & Aluminum Cocktail). Glyphosate also kills beneficial bacteria in the human gut and interferes with the synthesis of amino acids (MIT Researcher's New Warning: At Today's Rate, Half Of All U.S. Children Will Be Autistic By 2025). When certain microbes such as E. coli and Salmonella are exposed to glyphosate, they can become more resistant to antibiotics (Study Links Widely Used Pesticides to Antibiotic Resistance and Sublethal Exposure to Commercial Formulations of the Herbicides Dicamba, 2,4-Dichlorophenoxyacetic Acid, and Glyphosate Cause Changes in Antibiotic Susceptibility in Escherichia coli and Salmonella enterica serovar Typhimurium).

Glyphosate moves into the soil from the plant, and there it effects the large-scale destruction of beneficial soil microbes, even nitrogen-fixing bacteria. Glyphosate prevents plants from getting the nutrients they need. It immobilizes manganese, copper, potassium, iron, magnesium calcium and zinc (Scientist warns of dire consequences with widespread use of glyphosate). It kills off earthworms crucial for decomposing organic matter (Glyphosate disrupting root systems, destroying soil nutrients and eliminating earthworms and Dr Santadino: Glyphosate Destroys Earthworm Eisenia fetida Populations). It "stimulates the virulence of pathogens that kill plants." It causes the proliferation of fungal diseases and lowers crop yields. Weeds develop resistance to glyphosate, and this causes farmers to apply glyphosate in larger doses (Glyphosate decreases yield, seedling quality of Roundup Ready soybeans; increases rate of fungal disease). Some of the supposed "inert ingredients" applied along with glyphosate compound its deadly effect and are, in certain cases, more deadly than glyphosate itself (Weed-Whacking Herbicide Proves Deadly to Human Cells).

In early 2015 the World Health Organization declared that glyphosate and 2,4-D are probably carcinogenic. In May of 2015, the International Society of Doctors for the Environment made a compelling Appeal to European governments: "To immediately and permanently ban, with no exceptions, the production, trade and use in all the EU territory of glyphosate-based herbicides and four insecticides assessed by the International Agency for Research on Cancer (Ruthless power and deleterious politics: from DDT to Roundup.

Glyphosate is a highly lethal poison. It belongs nowhere within agriculture. It should be totally banned in Vietnam and throughout the world (Why Glyphosate Should Be Banned – A Review of its Hazards to Health and the Environment, Republished study: long-term toxicity of a Roundup herbicide and a Roundup-tolerant genetically modified maize and Glyphosate News). This video by Theirry Vrain sums up the dangers of glyphosate in a powerful way: Engineered food and your health: the nutritional status of GMOs.

The use of groundcovers such as the perennial peanut is, by contrast, a safe and effective way of controlling weeds in an orchard setting. Also, one should not overlook the safety and effectiveness of something as simple as vinegar in controlling weeds (Organic Weed Controls ~ Vinegar as an Herbicide).

Leguminous plants such as the perennial peanut have a greater root volume than perennial trees, "allowing for a much greater absorption of mineral nutrients" (Influence of Cover Crop Cultivation). In acidic soils, phosphate ions might precipitate with Al and Fe cations. The perennial peanut produces organic anions that displace sorbed phosphate, making phosphorous more available to plants. This is particularly important in Lam Dong province where most soils contain high levels of gibbsite. There's enough phosphorous in some soils to sustain maximum plant growth for the next 100 years or more. It's only a question of making it available to plants.

When adequately shaded, the rhizoma perennial peanut can grow to a height of over 50 cm, making it is easy to cut and carry. Partial shade is essential in getting the perennial peanut to shift from reproductive to vegetative growth. Perennial peanut can be cut right down to rhizome level, as seen in the picture on the right. It can be harvested every 45 days (Performance of Perennial Peanut). The feed conversion ratio of rabbits fed perennial peanut is an astounding 2.6, lower than that of alfalfa and kudzu (Perennial Peanut: Developments in Animal Research).

The perennial peanut flowers throughout the year and is a good source of food for bees. Maintaining a healthy population of bees is vital for the pollination of many plants (U.S. Sets Plan to Save Honey Bees and Other Pollinators and Are Bees Back Up on Their Knees?). Since the perennial peanut flowers in existing orchards throughout the year, perhaps it's not necessary to leave a lot of land uncultivated to support wild pollinators (Our Bees, Ourselves).

Hundreds of thousands of people in Vietnam could be involved in harvesting and fermenting perennial peanut. During the fermentation of the perennial peanut, some cellulose and hemicellulose is broken down. The large intestine of the pig is well adapted to breaking them down further.

THE PERENNIAL PEANUT, EARTHWORMS AND SOIL

The detritus from the perennial peanut provides ideal conditions for the growth of earthworms. With the perennial peanut, there can be as many as 10 to 20 million earthworms per hectare. Such a large number of earthworms produces on site over 100 tons of vermicompost per hectare per year. In the picture on the right we see huge quantities of earthworm castings freshly deposited at the base of the perennial peanut stems. The perennial peanut is paradise for earthworms.

Earthworms are "keystone species" in soil food webs, and they should account for up to 90% of invertebrate biomass within the soil (Edwards, 2004). A soil without earthworms is a soil that has died, and a soil that has died becomes forever dependent on chemical fertilizers, pesticides, herbicides and fungicides (How Chemical Fertilizers and Pesticides Affect Earthworm and Soil Health):

Inorganic fertilizers applied to fields promote an explosion of higher plant production than occurs in fields that are not fertilized. This quickly throws the soil ecosystem out of balance leading to an amphetamine-like spike and crash of earthworm and other microorganism populations. Nitrogen fixing bacteria are also often negatively affected. This again leads to a cycle requiring repeated and more intense use of nitrogen based chemical fertilizer.

Earthworms till and aerate the soil (no need for humans to till the soil). They continually transport and transform organic matter within the soil. In so doing, they greatly improve soil tilth. They neutralize soil pH. They counter nematode-induced crop losses (Potential Reinforcing Role Of Earthworm Species In Plant Resistance To Parasitic Nematodes and Interactions between earthworms and plant-parasitic nematodes and Earthworm activities induce better resistance to plant-parasitic nematodes in banana and Biological Control of Plant-parasitic Nematodes and Earthworms enhance plant tolerance to nematode infection through non-trophic effects of ecosystem engineering).

Through the ingestion and mixing of soil in the gut of the earthworm, the concentration and chemical forms of phosphorous are modified, making phosphorous more available to plants (Effects of Earthworms on Phosphorus Dynamics – A Review). "Earthworm casts increase the nutrient availability of the soil by 1.4 fold for calcium (Ca), 3.0 fold for magnesium (Mg), 11.2 fold for potassium (K), 7.4 fold for phosphorus, and 4.7 fold for nitrate-nitrogen (NO_3^--N) (Biological Charcoal is a valuable resource for Agriculture). Humic and fulvic acids produced in the gut of the worm coat aluminum and iron oxides and reduce phosphorus sorption. The presence of earthworms in the soil "decreases runoff up to 2-15 times by increasing soil water infiltration."

In New Zealand and Tasmania, "the introduction of earthworms into perennial pastures (where there were no earthworms previously) initially increased pasture growth by 70-80%, and increased it by 25% over the long term" (No Dig Gardening). Earthworms leave castings on the surface of the soil. "In favorable conditions they can bring up about 50 t/ha annually, enough to form a layer 5 mm deep. One trial found worms built an 18-cm thick topsoil in 30 years" (How earthworms can help your soil). For more on the amazing benefits of earthworms in the soil, see Earthworms.

Like the perennial peanut, earthworms play an important role in solving the gibbsite problem, and like the perennial peanut, they also play an important role in solving problems of runoff and soil erosion. This combination of perennial peanut and earthworms does great things for the soil. Finally bees and earthworms are vital to agriculture, and the perennial peanut, in providing throughout the year both nectar for bees and detritus for earthworms, greatly benefits both.

David Pimentel of Cornell University sees soil erosion as "one of the most serious environmental and public health problems facing human society" (SOIL EROSION: A FOOD AND ENVIRONMENTAL THREAT). He writes that "each year an estimated 10 million ha of cropland worldwide are abandoned due to lack of productivity caused by soil erosion," that "approximately 75 billion tons of fertile soil are lost from world agricultural systems each year," and that "overall soil is being lost from land areas 10 to 40 times faster than the rate of soil renewal." "Worldwide, the 1.5 billion ha of land now under cultivation are almost equal in area to the amount that has been abandoned by humans since farming began" (Paradigm Shift Urgently Needed).

Xuan Huong Lake, located right in center of Dalat, has to be regularly dredged due to the fact that it fills up with sediment. When Xuan Huong Lake was last dredged in 2010, the entire lake of 32 hectares had to be drained, and more than 300,000 cubic meters of watery sludge were excavated and loaded onto trucks. As trucks headed for various informal dumpsites, sludge leaked out, and paved streets were covered with sludge (picture on the right). The dumping of this sludge caused huge environmental pollution (Dredged mud threat to scenic waterfall).

Solving the problem of erosion in the 2,800 hectares that drain into the lake makes a lot more sense than periodically dredging the lake and trying to clean up the pollution that this dredging creates.

Soil erosion is a serious problem throughout Vietnam. "Researches show that over a large area of 22.95 million ha, accounting for 69.3% of the total land area of the country, the degree of erosion potentially ranges from 50 to 4,500 tons/ha/year" (State of the Environment). Soil erosion in the hilly and mountainous regions of Vietnam, especially where coffee is grown, is reaching catastrophic levels. With erosion, the soil loses plant nutrients, and to offset nutrient loss, large amounts of chemical fertilizers are applied. The application of chemical fertilizers poisons the soil and strips it of organic matter. This in turn accelerates the rate at which soil degrades and erodes.

But soil that is not tilled, soil that is rich in organic matter and humus, soil that is wisely intercropped, soil that is bound together by endless networks of rhizomes of plants such as the perennial peanut, soil that is glued together into aggregates through the secretion of earthworms, soil that is glued together into aggregates through the secretion of glomalin by AM fungi, soil that is bound together by fungal hyphae, soil that is rich in extracellular polymeric substances, soil that is entangled with filaments secreted by colonies of cyanobacteria, soil that is rich in micro- and macro-pores, soil that is riddled with earthworm tunnels and is easily infiltrated by rainwater, soil that is alive with countless microbes and plants in mutualistic association, soil that is regularly enriched with mulch, compost, vermicompost and biochar – such soils do not degrade faster than their rate of renewal. Such soils are sustainable.

Janice Snow, in a truly remarkable thesis called Misunderstanding Soil Ecosystems, writes that we have to stop looking at soil as a material or chemical medium to support the growth of plants. She calls this the traditional, static, reductionist, physical/chemical model of soil. This model relies heavily on chemical fertilizers, hybrid seeds, irrigation, pesticides, herbicides and fungicides. A few large transnational companies dominate the sale of these commodities. In essence, it's raw, crass capitalism. It's all about lobbying politicians, making gifts to universities, and corralling and abusing science to suit selfish monetary goals. No consideration whatsoever is given to the offsite pollution of water and land, or the onsite loss of soil carbon.

Snow also critiques the Black Box model understanding of soil organic matter and soil quality. Here soil microbial biomass is measured as a "single undifferentiated unit." This approach, argues Snow, still portrays a "reductionist image of the diverse life in soil biomass." In the Black Box model, land is not tilled, but this no-till agriculture is promoted in the context of the "judicious use" of chemical fertilizers together with the greatly increased use of herbicides, pesticides and fungicides. Large companies such as Monsanto, Syngenta, Dow, Bayer and BASF are avid supporters of the Black Box model.

Snow even critiques the Soil Food Web model. This model harkens back to the thought of Charles Darwin, where notions of competition, struggle, war and survival are paramount. "The term food web suggests the field's emphasis on who eats whom and its historic focus on two feeding (or "trophic") levels: plants and plant eaters (herbivores), and predators and prey."

Instead of viewing soil in mechanistic terms, as a Black Box or as a Food Web, Snow argues that we should view soil in organismic terms. "Mutualism, not competition, is to many soil ecologists the dominant driver in natural soil ecosystems." Here we see mutualistic networks teeming with microbial, plant and animal life. Mutualists self-organize in complex, interdependent communities. Some mutualists cannot survive for a moment in isolation. Mutualists work together in regulating the physical structure of their habitat. They communicate with one another in many different ways. They work in exquisite harmony with one another.

For example, plant exudates account for as much as 20% to 25% of carbon fixed by photosynthesis. These exudates include vitamins, enzymes, and complex carbons that greatly benefit soil microbes. At the same time, soil microbes supply nutrients, growth hormones, anti-pathogenic agents and other compounds to plants. Plants supply carbon compounds to AM fungi, and AM fungi in return inject phosphorus, water, zinc, nitrogen and trace nutrients directly into plant roots. Fungal hyphae also "increase root resistance to disease-causing pathogens."

Nutrients are protected inside fungal hyphae where pathogens cannot access them. Also, when nutrients are tucked away inside hyphae, this slows down "litter decomposition and the release of CO_2." The fungal slowing of decomposition is an important carbon-mitigating factor, especially when we take into account the fact that fungal mycelium can extend several meters below the surface of the soil. If we add to all of this the fact that fungal hyphae are 60% chitin, that glomalin alone can account for up to 60% of carbon in undisturbed soils, and that biochar not only contains carbon in an extremely stable form but also promotes the growth of AM fungi, a powerful strategy begins to emerge on how to sequester carbon and fight global warming.

Soil ecosystems can store "more carbon and for longer periods than above ground vegetation." In fact, soils can "contain twice as much organic carbon as vegetation." Some scientists estimate that in as little as 10 years, we could reduce atmospheric carbon levels down to 350 ppm simply by abandoning conventional agricultural practices that abuse the soil (The Carbon Underground brings down-to-earth solution to climate change).

If a plant is deficient in iron, it might exude compounds to stimulate the growth of iron-releasing bacteria. If a plant is under attack by pathogens, it might exude compounds to stimulate the growth of microbes that produce antibiotics. The complexity here is amplified by the fact that a variety of mycorrhizal fungi are likely involved, "each specializing in different organic compounds." Cross-species interdependencies abound, as we have noted previously: nitrogen fixing bacteria supply nitrogen to AM fungi in return for a share of the phosphorus the fungi supplies to the plant in return for the carbon compounds supplied by the plant. These are just a few of the many gift exchanges within soil.

In this mutualistic model, ancient systems of integrated crop and livestock production are strongly encouraged. Here chemical fertilizers are not needed, since they would disrupt to a large extent the delicately balanced mutualistic edifice. Here, too, soil productivity far surpasses that of conventional agriculture. Snow quotes from Maser who vividly describes the soil in organismic terms as "the great placenta of the earth." In India the soil is called "Sacred Mother." If only science had such deep reverence for soil. If only mutualism could become the dominant force in human interactions, and in economic and political theory.

THE LACTIC ACID FERMENTATION OF PIG FEED

Heat treatment, fry-cooking, grinding, milling, hulling, husking, chopping, soaking and germination are all useful strategies within certain contexts (Alternative plant protein sources for pigs and chickens in the tropics – nutritional value and constraints: a review). Coffee pulp, of course, can be fermented and fed to pigs, chickens and cows. But in the case of a big demand for larval protein and fats, it can also be fed to BSF larvae, as seen in this video. Coffee mucilage can be removed mechanically from the freshly pulped coffee bean, fermented and fed to pigs. But it can also be processed into a delicious molasses using gasifier heat. BSF larvae cannot be fermented, as explained in Commercial production of anti-microbial products from the Black Soldier Fly. Live larvae, red worms and fresh sugarcane billets, as previously explained, can be placed on pig bedding as a source of nutrition and entertainment for pigs. But why, in general, does it make sense to ferment feed?

"The stomach and small intestine of pigs are lactic acid habitats, in that lactic acid is the main microbial fermentation product found therein" (Isolation of lactic acid related bacteria from the pig mucosal proximal gastrointestinal tract). The gut of the pig can be thought of as a huge "microbial organ" made up of about one quintillion (10^{18}) self-regulating bacterial cells all in communication with one another. The pig lives in tight mutualistic relationship with this complex, always changing, organ or superorganism. It provides nutrients to the pig, and it protects it from pathogens by means of colonization resistance that relies on niche exclusion. So mutualism not only characterizes what happens within the soil. It also characterizes what happens in the gut of the pig.

Potential pathogens are always present in the gut of the pig. "Life here is a delicate balance between health and disease." If the pig is supplied with fermented feed each day, this balance is easily fostered and maintained. But if the gut of the pig is hit with antibiotics, this balance is destroyed. Pathogens, especially antibiotic-resistant pathogens, take over.

Lactic acid bacteria consume water-soluble carbohydrates and produce lactic acid. As the pH within the fermentation broth drops to 4.0 or below, the pH behind the cell membranes of feed-spoiling microorganisms and pathogens is lowered to destructive levels. Moreover, lactic acid bacteria produce bacteriocins and antibiotics that destroy undesirable microbes (Discovering new compounds against bad bacteria). With fermentation, feed can be preserved for extended periods of time, and bacterial counts can be reduced to virtually nothing. “All common bacteria which cause food-borne infections are inhibited at pH values below 4 and in the case of Clostridium botulinum toxication is prevented below pH 4.5” (8. Health Implications of Feeding Silage).

But the advantages of using lactic acid bacteria go far beyond feed preservation, feed management and pathogen destruction within feed. Lactic acid bacteria regulate the balance of microbial populations in the gut, they stimulate the immune system and they inhibit the growth of pathogenic gut bacteria, as further explained in this paper, Lactic Acid Bacteria, Probiotics and Immune System.

In a doctoral thesis entitled Developments and Benefits of Liquid Feeding through Fermentation for the Post-Weaned Pig, we see clearly the benefits of fermentation. In this experiment, some pigs were fed a fermented liquid feed, some a non-fermented liquid feed, some a conventional pelleted dry feed and some were left to continue to suckle the dam for two weeks post weaning. Potential porcine pathogens were deliberately added to all four treatments.

The study concluded that no coliform bacteria were detected at the terminal ileum section of pigs fed fermented liquid feed, whereas all of the other treatments showed significant levels. “The main effect of feeding a fermented diet was to increase the lactobacilli numbers along the gut, with the greatest influence at the terminal ileum.” Compared to the other treatments, the ratio of lactobacilli to coliforms in fermented feed was “dramatically increased.” The study concluded that unfermented liquid feed “represents a risk to young piglets since there is a potential for pathogenic bacteria to grow in the feed and hence be ingested by the piglet.”

Animal and fish feeds are often contaminated by multidrug-resistant salmonella (see Why is it so difficult to eradicate salmonella? and Feed likely source of salmonella contamination on pig farms and Salmonella enteric in Commercial Swine Feed). Fermentation is an easy way to reduce counts of Salmonella and other pathogens to safe levels.

We see in another doctoral thesis by Hoang Huong Giang that probiotics were added to the feed of growing pigs in Vietnam (Impact of bacteria and yeast with probiotic properties on performance, digestibility, health status and gut environment of growing pigs in Vietnam). “Giang′s studies showed clearly that by combining suitable probiotic strains of Bacillus, Saccharomyces and LAB, positive effects on growth, feed conversion, and nutrient digestibility and a decrease in the occurrence and severity of diarrhea can be obtained, particularly in newly weaned pigs.” Her study showed that probiotic complexes “can be used as an alternative to antibiotic feed additives in pig production under conditions in Vietnam.” But rather than supplement pig feed with probiotics, why not ferment all feed? The pig feed itself serves as the substrate for the growth of probiotics.

In this paper by Demeckova (Review: The influence of probiotic use in sows and neonatal piglets on performance measures and diarrhea in suckling piglets), we see that if the feed of the sow is fermented, the health of her piglets is improved. If the sow receives fermented feed, the gut of the piglet has a much better chance of functioning correctly. If the sow receives fermented feed, there will be low coliform counts and high LAB counts in the feces of the piglet.

Lactic acid bacteria play a vital role in regulating both gastric and urogenital pH (Antibacterial and Probiotic Properties of Lactic Acid Bacteria Isolated from Chicken Intestine, Entrails of Swine, and Soil against Gastrointestinal and Urogential Pathogens). Lactic acid bacteria "synthesize water-soluble vitamins such as those included in the B-group (folates, riboflavin and vitamin B12 amongst others)" (B-group vitamin production by lactic acid bacteria--current knowledge and potential applications). They produce menaquinone compounds (vitamin K2) (Production of menaquinones by lactic acid bacteria). They increase the bioavailability of amino acids, particularly lysine (Fermented Food: Benefits of Lactic Acid Fermentation).

Lactic acid bacteria break down and destroy pesticide residues on vegetables. In this study (Biodegradation of chlorpyrifos by lactic acid bacteria during kimchi fermentation), chlorpyrifos, coumaphos, diazinon, parathion and methylparathion were all degraded by certain strains of lactic acid bacteria. "CP [chlorpyrifos] was degraded rapidly until day 3 (83.3%) and degraded completely by day 9." Also in this regard, take a look at METABOLIC RESPONCES OF LACTIC ACID BACTERIA TO ORGANO PHOSPHORUS COMPOUNDS. Furthermore, "Lactic acid bacteria have been identified as potent tools for the decontamination of heavy metals, cyanotoxins and mycotoxins" (Combining strains of lactic acid bacteria may reduce their toxin and heavy metal removal efficiency from aqueous solution).

Lactic acid stimulates pancreatic activity and the secretion of digestive enzymes. It breaks down anti-nutrients and hard-to-digest carbohydrates and proteins. Lactic acid bacteria decrease levels of phytic acid (or phytate when in salt form) in grains (Phytase Activity of Lactic Acid Bacteria Isolated from Dairy and Pharmaceutical Probiotic Products). Phytate is the major source of phosphorus in plant seeds, and it can form insoluble complexes with minerals. Lactic acid bacteria improve the bioavailability of minerals such as phosphorous, as well as calcium, iron, zinc and magnesium. See further the New York Times bestseller, The Art of Fermentation by Sandor Ellix Katz.

The Japanese have long understood the value of probiotics for human use (Current Marketplace for Probiotics: A Japanese Perspective). "In Japan, probiotics are available as both foods and drugs." Probiotics are used today in many Japanese hospitals. "Health targets for probiotic FOSHU marketed in Japan include gastrointestinal conditions, immunity, allergy, cold and influenza-like symptoms, cholesterol levels, blood pressure levels, and diabetes." Probiotics are not limited to lactic acid bacteria. They also include yeast (Nutritional Yeast).

Probiotics, of course, are just as beneficial in the diet of pigs as they are in the diet of humans. Moreover, pigs have a strong preference for fermented feed. The palatability of fermented foods ranks quite high, provided concentrations of acetic acid and biogenic amines are low.

Since January 2006 the European Union has wisely banned the use of antibiotics as growth promoters in monogastrics. "In recent decades, organic acids (acidifiers) have been used as potential alternatives to antibiotics in monogastric animals' diets in order to improve growth performance and prevent diseases" (The use of organic acids in monogastric animals - swine and rabbits). But once again, why add organic acids as external inputs? Instead the farmer has only to ferment his feed.

It is highly recommended that biochar in small amounts be added to whatever is being fermented. Biochar provides surface area for fermentation microbes. For more on fermentation, see [Empowering the Poor through the Fermentation of Waste Biomass and Co-cropped Biomass].

When a pig is fed primarily fermented feed, when the bedding is sprayed daily with a probiotic liquid, and when the pig eats bedding, the microbes within the feed, the microbes within the gut and the microbes within the bedding all closely match. The feed of the pig, the gut of the pig and the bedding of the pig all become "lactic acid habitats." Since pig feed is fermented, and since feed and bedding are enriched with biochar, this might explain why the feces of pigs raised in this unconventional way has very little odor.

FARMERS SHOULD BUY NOTHING FROM COMMERCIAL FEED COMPANIES

When plants and animals are raised in proximity to one another, plant biomass can be transformed into feed, and animal waste can be transformed into fertilizer. For every hectare of land, there should be a certain number of animals or birds both supporting it and dependent upon it. After World War II came the rise of the factory farm, and the ancient wisdom of growing plants and animals together was abandoned. As Wendell Berry wrote back in 1977, "The genius of America farm experts is very well demonstrated here: they can take a solution and divide it neatly into two problems."

In feeding his pigs, we suggest that the farmer buy nothing from commercial feed companies. Conventional pig feeds produced by Cargill and other commercial feed companies are quite expensive, in Vietnam they all contain antibiotics, and when farmers are cleverly lured into buying them, they constitute more than 70% of the cost of raising pigs (Farms Hit by High Feed Prices). Also, in Vietnam animal feed prices are "about 15 to 20% higher than in China, Thailand and Indonesia." To the extent that farmers learn to gather, grow, ferment and make feed, the cost of feed can drop to almost nothing. The appeal we make in getting farmers to switch to this new way of raising pigs is not environmental but purely economic: *you can make a lot more money*.

As Vietnamese farmers learn to make and ferment their own feed, they could also make a big difference in the country's balance of trade. Vietnam is the world's second largest producer of rice after Thailand. Yet this huge export of rice does not match what Vietnam imports to feed its animals. "Figures from the agriculture ministry showed that Vietnam imported $3 billion of animal feed products in 2013, 2 percent more than rice export revenues for the year, and more than $1 billion in corn, soybean and wheat flour for processing animal feeds, a surge from the previous year" (Vietnam livestock fed mostly by imports).

China imports a lot of corn and soya to feed its pigs. Some reckon that "more than half of the world's feed crops will soon be eaten by Chinese pigs. Already in 2010 China's soy imports accounted for more than 50% of the total global soy market" (Empire of the Pig). Vietnam and China should not rely on imported animal feed products, and human food such as corn and soya should never be fed to animals. The feed conversion ratio in the case of a pig is dreadfully low. It takes about 6 kg of feed to produce one kg of pork. Instead of trying to put an end to such inefficiency and waste, "the Chinese government subsidized pork production by $22 billion in 2012. That is roughly $47 per pig."

But it's not simply a question of eliminating inefficiency and redressing trade imbalances. The pigs raised in this unconventional way are remarkably lean and fit. At the moment some farmers employing this unconventional approach can sell their pigs to traders for about twice more than pigs raised in the conventional way. At the level of the consumer, the taste of this unconventional pork is outstanding.

FARMERS SHOULD BUY NOTHING FROM CHEMICAL FERTILIZER COMPANIES

In growing the plants needed to feed his animals and in growing all other plants, the pig farmer should buy nothing from chemical fertilizer companies. The application of chemical fertilizers is highly inefficient. Currently about 40% of the nitrogen, 80% to 90% of the phosphorous, and 50% to 70% of the potassium applied are not assimilated by plants (Malavolta 2006). In a hilly or mountainous setting, these figures are far worse. The runoff from chemical fertilizers causes serious environmental problems.

Runoff from chemical fertilizers in the US has created a huge dead zone in the Gulf of Mexico of over 15,000 square km. "The Gulf's dead zone is now one of the largest hypoxic zones of water in the world and growing in size" (The Gulf of Mexico's Dead Zone). Other bodies of water in the US and Canada are also affected by agricultural runoff (A large algae bloom is planted on the western edge of Lake Erie).

Lake Erie in particular has received a lot of attention lately due to the fact that its water has been declared unfit for drinking, bathing and even washing dishes. Roughly 70,000 farmers over an area of four million acres are dumping phosphorous into Lake Erie (Spring Rain, Then Foul Algae in Ailing Lake Erie and Tap Water Ban for Toledo Residents). This abundance of phosphorous gives rise to the growth of blue-green algae (cyanobacteria) containing microcystin, "a toxin that can cause nausea, vomiting, diarrhea, severe headaches, fever, and even liver damage." Some 636 miles of the Ohio River has been contaminated with the same toxic algae. (Toxic Algae Outbreak Overwhelms a Polluted Ohio River).

This problem is not confined to Lake Erie or and the Ohio River. "Poisonous algae are found in polluted inland lakes from Minnesota to Nebraska to California, and even in the glacial-era kettle ponds of Cape Cod in Massachusetts"(Behind Toledo's Water Crisis, a Long-Troubled Lake Erie). Lakes throughout the entire US are affected (see graph shown in The Toxic Algae Are Not Done With Toledo. Not By a Long Stretch). The runoff from chemical fertilizers is the main culprit here. It represents inefficiency and pollution on the grandest of scales.

This problem is actually a "worldwide menace" (Cyanobacteria Are Far From Just Toledo's Problem). Fertilizer runoff in eroded, hilly, highland areas of Vietnam is particularly bad. Most streams, rivers, lakes and coastal areas are affected. Agricultural runoff plays a major role in the pollution of Xuan Huong Lake in Dalat. Dead fish are often seen on the surface of the lake (Japanese company helps Dalat tackle pollution in lakes).

When farmers apply chemical fertilizers, many do not follow guidelines with respect to what type to apply, how much to apply or when to apply (Vietnam – Urban Agriculture). Very little soil testing is done. Traders in chemical fertilizers are predominately profit-driven, and they typically give bad advice to farmers. Not knowing what to do, farmers fall into the trap of thinking that more is better.

This overuse of chemical fertilizers in Vietnam contributes to high levels of water pollution - far worse than in the United States.

But perhaps the biggest problem relating to the use of chemical fertilizers lies not in water pollution but in soil pollution. Chemical fertilizers destroy the diversity of beneficial microorganisms within the soil, and this lack of diversity makes plants highly susceptible to pests and diseases. Chemical fertilizers disrupt the activity of protozoa, arbuscular mycorrhizal fungi, mycorrhiza helper bacteria, actinomycetes, N-fixing bacteria, P-solubilizing bacteria, nematode-killing fungi, iron-releasing bacteria and many other beneficial soil microorganisms. When the mycorrhizosphere does not function properly, the soil dies. Chemical fertilizers act like a "slow poison" for the soil (Earthworms Vermicompost).

When ammonium sulfate is applied to the soil, sulfuric acid is produced. This potent acid kills beneficial soil-dwelling organisms. When ammonium nitrate is applied to the soil, free oxygen oxidizes organic matter and, and the soil is stripped of organic matter and no longer retains moisture. Without moisture, farmers are forced to irrigate, and water tables are depleted. When urea is applied to the soil, toxic anhydrous ammonia and caustic ammonium hydroxide are produced. Both kill soil microbes. When urea formaldehyde is applied to the soil, formaldehyde dissolves in water and kills soil microbes. When potassium chloride is applied to the soil, free chloride is released into the soil, and it is not uncommon to see chloride levels as high as 50 to 200 ppm. Since it only takes 2 ppm of chlorine to sterilize drinking water, soil microbes are again wiped out.

When triple-super-phosphate fertilizer is applied to the soil, it often contains arsenic, lead, nickel, cadmium, chromium and other toxic substances (Phosphate fertilizer is a main source of arsenic in areas affected with chronic kidney disease of unknown etiology in Sri Lanka). These heavy metals also kill soil microbes. Calcium phosphate typically contains polonium-210, and when applied to the soil, it contaminates the soil and all that it touches. Polonium-210 is about 250,000 times more toxic than hydrogen cyanide. When tobacco is fertilized with calcium phosphate, polonium-210 makes its way into the tobacco leaf, and it is the "primary cause of lung cancer in smokers" (Radioactive Fertilizer—The Surprising Primary Cause of Lung Cancer in Smokers and see further Waking A Sleep Giant). The same polonium-210 from calcium phosphate fertilizer contaminates meat and dairy products.

These are just a few of the problems associated with the use of chemical fertilizers (see Effects of some synthetic fertilizers on the soil ecosystem and Soil Diversity: A Key for Natural Management of Biological and Chemical Constitute to Maintain Soil Health & Fertility). "Despite ongoing genetic and cultural improvements, a 66% global decrease has occurred over the past 40 years in the agronomic efficiency of fertilizer N" (Synthetic Fertilizer Degrades Soil Carbon and Nitrogen), while its use per hectare has increased seven times. "The use of chemical fertilizers this year [2015] will likely generate more greenhouse gas emissions than the total emissions from all of the cars and trucks driven in the US" (These New Synthetic Nitrogen Fertilizers Are about to Blow Up).

Chemical fertilizers not only pollute water and soil, but they are also responsible for an increase of nitrous oxide in the atmosphere (Fertilizer use responsible for increase in nitrous oxide in atmosphere, Agricultural Sustainability and intensive production practices and Corn Farms are Cooking the Planet). "After carbon dioxide and methane, nitrous oxide (N_2O) is the most potent greenhouse gas, trapping heat and contributing to global warming. It also destroys stratospheric ozone, which protects the planet from harmful ultraviolet rays." Nitrous oxide has 300 times the carbon-trapping capacity of carbon dioxide.

Chemical fertilizers also release nitrogen oxide which "destroys so-called "good" ozone, which shelters life from damaging ultraviolet radiation; it also fuels production of ground level ozone, the main constituent in smog that is widely known to exacerbate human respiratory ailments" (Nitrogen Fertilizer: Agricultural Breakthrough--And Environmental Bane). "Nitrogen fertilizer is responsible for the majority (70% in some estimates) of greenhouse gas emissions associated with the production of crops" (Paradigm Shift Urgently Needed).

The investment banker, Jeremy Grantham, in a conversation with Mark Bittman of the New York Times, summed it up so well (A Banker Bets on Organic Farming):

The U.S.D.A., the big ag schools, colleges, land grants, universities — they're all behind standard farming, which is: sterilize the soil. Kill it dead, [then] put on fertilizer, fertilizer, fertilizer and water, and then beat the bugs back again with massive doses of insecticides and pesticides.

Applying chemical fertilizers to the soil is analogous to injecting animals with antibiotics. Both destroy the diversity of beneficial microbes, and both open wide the door for the proliferation of pathogens.

Previously we recommended that under no circumstances should farmers or veterinarians be allowed to administer antibiotics to anything destined for human consumption. Similarly we recommend a total ban on the use of chemical fertilizers. The first step in the clean-up of the Gulf of Mexico, Lake Erie, Xuan Huong Lake or any other contaminated body of water should be a total ban on the use of chemical fertilizers. There are no situations in which chemical fertilizers can be "judiciously" used. If farmers cannot raise plants without the use of chemical fertilizers, they should not be in the business of raising plants. If scientists cannot come up with a set of guidelines showing farmers how to raise plants without the use of chemical fertilizers, they're doing bad science.

Some farming villages in India fertilize primarily with vermicompost and have completely abandoned the use of chemical fertilizers. This switch to vermicompost has resulted in reduced water for irrigation, reduced pest attacks, reduced termite attacks, reduced weed growth, faster seed germination, more rapid seedling growth, much higher crop yields, and better tasting fruit and vegetables.

We are not suggesting that only vermicompost be added to the soil. In this essay, we highlight the importance of running fresh putrescent fecal material (Type 2 waste) in sequence through the guts of both larvae and red worms. But there is a lot of non-putrescent organic waste (Type 3 waste) that cannot be processed through the combined action of larvae and red worms. This material is best composted thermophilically (Thermophilic Composting). One of the cheapest ways to compost thermophilically lies in the use of a compost fleece. We recommend that biochar be added to the material to be composted.

Biochar has qualities that neither vermicompost nor compost possesses (Biochar for Environmental Management). Biochar can increase plant growth, usually in the range from 20% to 120% (Lehman and Rondon, 2006). However, in highly weathered soils in the tropics, with the use of biochar, productivity can increase by as much as 300%.

Be sure and look up the many biochar experiments carried out in Vietnam, Laos and Cambodia under the supervision of Dr. Thomas R. Preston. In the picture on the right, we see the results of one of his many rice hull biochar experiments, in this case, an experiment in growing water spinach. The rice hull biochar used in most of these experiments was produced in the top-lit, updraft gasifiers shown at the beginning of this paper.

In spite of a high ash content sometimes, the water-holding capacity of rice hull biochar is noteworthy (see picture on left). One kg of rich hull biochar holds about 3.2 liters of water. Most of the ash within rice hull biochar is composed of silica (typically over 90%).

Silicon is an important functional nutrient that provides increased pathogen and pest resistance; drought and frost tolerance; as well as an increase in the yield and quality of many agricultural crops. “Ample evidence is presented that silicon, when readily available to plants, plays a large role in their growth, mineral nutrition, mechanical strength, and resistance to fungal diseases, herbivory and adverse chemical conditions of the medium” (The Anomaly of silicon in plant biology). Silicon plays an important role in the growth of rice (The Role of Silicon in Suppressing Rice Diseases), and the return of the silicon within rice hull biochar back to the soil should be encouraged wherever rice is grown.

Rice hill biochar also contains significant levels of phosphorus, potassium, calcium, magnesium and sodium. “Gasified rice hull biochar provided sufficient phosphorus (P) and potassium (K) to the substrate to grow a geranium crop for six weeks without any additional P or K fertilizers (Gasified Rice Hull Biochar is a Source of Phosphorus and Potassium for Container-Grown Plants).

We suggest that all three types of transformed waste be incorporated into the soil: vermicompost from Type 2 waste, thermophilic or mesophilic compost from Type 3 waste, and biochar from Type 4 waste. Just as most uncultivated soils contain an indigenous vermicompost created through the action of earthworms, they also contain a fair amount of indigenous biochar created through the natural occurrence of brush and forest fires. By applying vermicompost, compost and biochar to the soil, we stay within the framework of natural processes that enrich the soil.

Macadamia shell biochar is shown in the picture below left. Palm kernel shell biochar is shown in the picture below right.

Such biochar can be used to make water filtration systems capable of removing 100% of synthetic organic compounds such 2,4-D and DDT from drinking water (Profile: Using Biochar for Water Filtration in Rural South East Asia). Water filtration systems for a small village can be constructed for less than $125 US. These water filtration systems are urgently needed in many parts of Asia.

For example, in certain areas of Laos, 40% of the children never reach age five due to the contamination of drinking water with pesticides, herbicides and other synthetic organic compounds. In Vietnam only 39% of the rural population has access to safe water (Water in Crisis – Vietnam). Inexpensive water filtration systems are very much needed in rural Vietnam (Herbicide blamed for cancer surge in poor Vietnamese hamlets). Char produced from bones is great for the removal of flouride and metal ions from water (more on this later).

Spent filter char does not present a diposal problem. It can be composted or fermented, and eventually returned to the soil. Certain strains of lactic acid bacteria can break down synthetic organic compounds. Be sure and read this excellent paper by Josh Kearns entitled Sustainable Decentralized Water Treatment for Rural and Developing Communities Using Gasifier Biochar.

COUNTERFEIT FEED AND FERTILIZER

The use of commercial feeds and chemical fertilizers in Vietnam is further complicated by the fact that a lot of them are counterfeit and adulterated. The local fertilizer market in Vietnam is "saturated with counterfeit and low quality products" (Vietnam's Fertilizer Market Update). At times the NPK content of some fertilizers used on coffee farms is only 10% of its stated value. "The use of low-quality and fake agricultural materials is rife in Vietnam accounting for almost 30 per cent of domestic supplies in Tien Giang Province, 48 per cent in Hai Duong Province and 38 per cent in Lam Dong Province" (Vietnamese to Clamp Down on Fake Fertilizer and Feed).

More than 90% of the fertilizers applied to coffee trees in the hilly areas of Lam Dong province never make it into the coffee plant: they run down the hill when it rains. If the Vietnamese farmer makes his own feed and fertilizer, he's in full control of quality, and if he applies vermicompost, compost and biochar to the soil, very little nutrients are lost when it rains. If he plants perennial peanut in which earthworms thrive, the situation is further improved.

THE PIG FARMER BECOMES STRONG AND SELF-RELIANT

In distilling rice wine or cooking meals, the pig farmer never has to turn to fossil fuel companies selling coal or bottled gas. In fueling his gasifier, he does not have to worry about the cost of low-grade biomass, since the biochar he produces always has a greater value than the biomass from which it was derived. In many cases, low-grade biomass such as rice hulls and coffee husks are free. He never buys antibiotics, since his pigs rarely get sick. He never buys de-worming medicine, since his pigs have no gastro-intestinal roundworms. He never buys sedatives, since his pigs are seldom under stress. He never buys pesticides, since his pigs are not bothered by flies. He never buys anti-inflammatory medication such as cortisone, since his pigs never suffer from leg weakness, bush foot or foot rot. He never buys growth hormones, since fermented feed enriched with biochar is all that is required in promoting vigorous and healthy growth. He never buys laxatives, since his pigs get plenty of exercise and are not constipated. He never buys soaps, anti-infection agents and disinfectants, since probiotics are far more effective and safe. In not buying any of these things, the farmer discovers that the cost to produce a kilogram of pork is far less than that in the US ($1.26 or 26,500 VND).

The pig farmer becomes strong and self-reliant. He's in a unique position of having to buy nothing from fuel, feed, fertilizer, chemical and pharmaceutical companies. He is no longer subject to the fragility and uncertainty of the global marketplace. Since 98% of the Vietnamese people eat pork, and since pork accounts for 76% of their total meat consumption, *the unconventional pig farmer as described in this essay becomes a key player in assuring the security of the supply of food within Vietnam.*

FARROWING CRATES

If we have failed to convince you of the brutality and inhumanity of conventional pig pens, we ask you to visit a large conventional pig farm anywhere in the world and go straight to the farrowing crates where sows nurse piglets. The farrowing crate was introduced in the late 1950s, and since then, many engineers have been involved in the sinister perfection of its design. If you are not able to visit a farm with farrowing crates, watch this video. The farrowing crate is a logical extension of the factory farm: bring the sow indoors, raise her under the filthiest of conditions, put her on a hard concrete floor, and make sure that she and her piglets occupy a minimum of space. All of this is made possible by means of the constant use of antibiotics.

In farrowing crates, you will see sows enclosed in steel cages with hard floors. Remember these sows, as previously explained, had suffered irreversible cartilage and bone damage at an early age. Now in the farrowing crate, these problems get far worse. Sows have no room to walk or even turn around. They become grossly obese. Even if given ample room, the older sows oftentimes are unable to walk. Some only have the strength to sit up, and when sitting up, they are often in a dog-sitting position with the hind legs in an awkward forward position. This dog-sitting position forces fecal material into the vagina of the sow and gives rise to urinary tract infections. Urinary tract infections are exceedingly painful, and they are the predominate cause of death in pigs over one year of age (Urinary Tract Infection in Sows - A review).

In the farrowing crate, the hind muscles of older sows often pull away from their attachment to the pelvis. Vertebrae in the spine can fracture. Sows suffer excruciating pain, and they are under enormous stress. They are usually covered in feces, urine and flies. Their feet and nipples easily become infected. Some sows are sedated. All are regularly injected with antibiotics. Consequently their milk is contaminated with high levels of antibiotics. The production of hormones regulating fertility is disrupted. The digestion of protein is impaired. Milk production is far from optimal.

From an economic point of view, it's disastrous. Lame or partially lame sows require constant care and treatment with antibiotics and anti-microbial sprays. In spite of the high input of labor and medicines, many sows are prematurely culled before they bear a fourth litter. Sows do not become profitable until they have born three litters, and if they are culled before the fourth litter, they do not "pay for themselves." This reduces the number of finisher pigs brought to market. Raising sows in the conventional way on concrete floors is a great way to lose money.

PIGLETS SUFFER AND DIE

The mortality rate of piglets who nurse upon such sows is high. The transmission of beneficial microbes from sow to piglet does not take place in an effective manner, while the transmission of many pathogenic microbes is greatly amplified. The transmission of pathogens starts in the uterus of the sow, it continues to a limited extent in the birth canal, and of course, a lot of pathogens are transmitted the moment piglets begin to suckle. Infection often spreads to the mammary glands of the sow, due in large part to the dirty concrete floor of the pen. Like urinary tract infections, infections of the mammary glands are exceedingly painful. Many sows suffer from both types of infection.

A study conducted on humans suggests that "babies may acquire an important part of their normal gut bacteria from the placenta" and that "the wrong mix of bacteria in the placenta may contribute to premature births" (Study Sees Bigger Role for Placenta in Newborns' Health). These findings help to explain why urinary tract infections in pregnant women are linked to an increased risk of premature birth. The placenta contains up to 10% bacteria by mass, and there is definitely, what one might call, a "placental microbiome." If a mother had urinary tract infections early in pregnancy, bad bacteria end up in the placenta and are passed on to the baby in the womb. If the placenta is not sterile as many doctors had thought, and if it harbors beneficial microbes that are important for the health of the baby, imagine what happens when antibiotics are administered.

These finding were confirmed by studies on mice, and the same might apply with regard to pigs. A sow raised in the conventional way often suffers from urinary tract and mammary gland infections. This infected sow could easily be passing on infection to the piglet via the placenta. When the sow receives antibiotics, the healthy placental microbiome is destroyed, and the microbiome in the gut of the newly born piglet does not function properly, leading no doubt to a variety of health problems.

Then to make matters worse, "soon after they are born, the teeth of piglets are often clipped" (Tooth Clipping). To discourage tail-biting later on in life, many piglets have their tails docked to a length of about 16 mm. Most male piglets are castrated (Welfare Issues for Pigs). "In the USA virtually all males are physically castrated at a young age (predominantly) with no anesthesia or analgesia (pain relief)"(The Pig Castration Site). The procedure is not done under sterile conditions, and piglets suffer terrible pain. Fortunately the European Union has taken steps toward ending surgical castration (Current situation of the castration of piglets in Europe).

It makes no sense to castrate. Only a small proportion of entire male pigs have boar taint: less than 10% (Entire Male Pigs). Also if the entire male pig is slaughtered at about 90 kg, boar taint in general is not an issue. One great way of reducing boar taint lies in the use of organic acids. "The addition of organic acids to diets can reduce the concentration of skatole present in the faeces and thereby reduce the boar taint problem of the meat." But once again we suggest that organic acids should not be administered as external inputs. Instead the farmer should ferment all feed. Adding biochar to fermented feed might also be an effective way of reducing boar taint.

For a short time there might be a bit of aggressive behavior among entire males within a pen. But as soon as one male establishes dominance, this aggression subsides. Such behavior is normal and natural and should be allowed to take place.

PIGLETS RAVAGED BY DIARRHEA

The use of antibiotics even begins prior to the conception: they are added to semen extenders used in artificial insemination. Antibiotics are then routinely administered to both male and female piglets before and after they are weaned. But this poses serious problems. "Lactic acid produced from lactose fermentation comprises 80 to 100% of organic acids in the stomach of the suckling" (Swine Nutrition). When antibiotics are administered to the piglet, the regulation of gastric pH is disrupted, milk does not clot as it should, and protein is not properly denatured. What happens next is hardly surprising.

Piglets get diarrhea. When normal flora within the gut of the piglet is disrupted by antibiotics, diarrhea is commonplace. The same type of C. difficile (PCR ribotype 078) appears in both humans and pigs (Clostridium difficile Infection Associated with Pig Farms), and interspecies transmission has been found to occur. Antibiotics also knock out beneficial clostridial clusters that promote gut health and a balanced immune system (Among Trillions of Microbes in the Gut, a Few Are Special). Clostridial clusters secrete intestinal mucus that "serves both as an antimicrobial repellent and a growth medium for friendly bacteria."

But it's not just bacteria as in C. difficile and PWD that the poor piglet must contend with. There's also the highly lethal porcine epidemic diarrhea virus (PEDV).

PEDV has now spread to 27 states within the US (Deadly pig virus spreads to Arizona; 27 U.S. states now affected). "Since June 2013 as many as 7 million pigs have died in the United States due to the virus" (Killer virus spreads unchecked through U.S. hog belt, pushing pork to record). This virus can also be found in China, Korea, Japan and Vietnam. The mortality rate of piglets infected with this virus often runs as high as 100%. In a more recent article, the number of piglets and young hogs that have died from PEDV has now reached 8 million (Virus Plagues the Pork Industry, and Environmentalists). This equates to about 100,000 deaths per week.

In the United States some farmers gut piglets that have died from PEDV and feed their shredded intestines to the sow in an effort to immunize her against the virus (Is That Sausage Worth This?). After the sow has suffered a totally miserable life in a farrowing crate, she is then led to cannibalize her disease-ridden offspring. It's quite unbelievable what humans will do to animals when greed and panic override all else. This is not animal husbandry. It's savagery.

To reduce the incidence of diarrhea among piglets and to reduce the high level of stress associated with being separated from the mother, there is good evidence to support weaning piglets at 28 days, instead of the usual 10 or 21 days (What is the best age for weaning piglets?). However, we suggest that the weaning age be extended beyond 28 days - perhaps even to 40 days. This 40-day period puts us in line with the minimum weaning age for organic pigs (EEC Regulation 2092/91). Some researchers recommend that weaning not take place until the 63rd day (Prolonged suckling period in organic piglet production). Prior to weaning, piglets should be given access to fermented feed so that they can gradually adjust to the change in diet.

Finally when it's time to bring a sow to slaughter, having spent most of her life in a farrowing crate, she often has to be dragged into the transport vehicle. *Once again, this is not animal husbandry but unjustifiable savagery which should be categorized as criminal.* How can humans inflict such pain and misery upon animals? Any scientist who argues in favor of farrowing crates is engaged in a depraved mental exercise that ceases to be science. Pigs are highly social and intelligent (Pigheaded: How Smart are Swine?), they have rich emotional lives, and they deserve to be treated with dignity (According Animals Dignity).

A SPACIOUS MATERNITY PEN WITH SOFT BEDDING

The farrowing crate is designed to prevent sows from lying down on their piglets and accidently killing them. But the real killer in this instance is not the sow but the hard concrete floor on which she and her piglets are raised. If we replace hard concrete with a soft cushion, piglets are rarely crushed and killed by the mother. Fresh rice hulls are particularly effective in this regard. They do not easily compact. They are elastic, and if pressed down, they readily spring back to their original volume.

So instead of a farrowing cage, the sow and her piglets should be housed in a spacious maternity pen of at least ten square meters (see previous pig pen drawings). A horizontal bar at the bottom of the maternity pen prevents her from accidently bumping or pressing a piglet against the wall of the pen. The floor of the pen is covered with a 60 cm-layer of dry biomass consisting mostly of rice hulls. The sow remains strong and alert (not weak, clumsy, obese and at times sedated), and she has ample space to avoid lying down on her piglets. After all, she is a mother, and she knows how to take care of her offspring when given the right conditions.

The urine of the sow and her piglets flows into the bedding, and feces is removed from the bedding quite often, in this instance, at least three times per day. The bedding of the maternity pen, the sow, her teats, and her piglets are sprayed several times a day with a probiotic liquid. The sow is able to walk around. Her feet, legs, teats, mammary glands and urinary tract no longer get infected. She leads a life free of pain, stress, infection, flies, disease, pesticides, sedatives, anti-infection agents and antibiotics.

A pregnant sow spends about 80% of her time lying down, and soft bedding assures that when she lies down, she does so in comfort. "Comfort is of vital importance for her health and welfare. Lack of comfort while lying increases the risk of decubital ulcers (pressure sores), fluid-filled bursae on the limbs (bursitis) and places strains on the locomotory system. Given that the majority of pregnant sows worldwide are kept on concrete floors, it is likely that their comfort needs are not being met" (Lameness in Pigs).

SOW AND PIGLETS ENGAGE IN NEST-BUILDING

The bedding on the floor of the maternity pen also enables the sow to make a proper nest. It is so sad to witness a sow trying to make a nest on a hard concrete floor. Nest-building is innate in domesticated pigs, and it "is one important part in the whole process of pre- and post-partum maternal behavior" (Nest-building behaviour in sows and consequences for pig husbandry).

"Explicit nest-building behaviour can clearly be classified as a behavioral need for the pre-partum sow."

When a sow cannot build a nest, she "may grind their teeth, bite and root at the rails and change positions frequently between standing and lying. These activities are accompanied by intermittent grunting, champing of the jaws and increased respiratory rate. Rooting with the nose and pawing with the front hooves is shown by sows on concrete floor during 'nest' preparation."

Not being able to make a nest, the sow becomes highly frustrated. She frequently injures herself to the point where her nose and gums severely bleed. Stress hormones are released. Her heart rate increases. Eventually she becomes totally exhausted in a futile attempt to build a nest. All of this can lead to slow parturition, stillbirth and lactation problems. Unable to build a nest, she becomes unresponsive to her piglets and unresponsive to their screams. She vocalizes a lot less with them. The chance of her crushing and killing them increases. Sometimes in total frustration she even savages her piglets (Savaging). The farrowing crate ends up doing precisely the opposite of what it was insidiously designed to do.

Even though many small farmers in Vietnam do not have farrowing crates, many leave the sow on a hard concrete floor where she is still unable to build a nest. The behavioral needs of the pre-partum sow are not met. Since she cannot build a nest, the sow is still under a high degree of stress and frustration. Not confined by the farrowing crate, she can present at times an even greater danger to her piglets.

But when a sow is placed in a maternity pen and given what she needs to build a nest, this "leads to better health and welfare of both the sow and the piglets." Litter size can increase in sows allowed to build nests, and "lower rates of mortality are documented in sows with better nest-building behavior. When the opportunity for nest-building is given, the duration of sucking periods is increased and the number of sucking periods terminated by the sow is decreased."

Even young piglets engage in nest-building: "Already at an age of six days, piglets perform basic elements of nest-building behavior." In the highland areas of Vietnam where it gets cool at night, piglets hunker down in the soft bedding of their maternity pen to keep warm. Infrared heat lamps are generally not needed. The maternity pen becomes an ideal nest for sow and piglets. All is closely aligned with what nature demands.

So this bedding concept makes it possible to completely do away with farrowing crates. By the way, do not let anyone try to convince you that farrowing crates are not commonly used on semi-industrial and industrial pig farms in Vietnam and throughout the whole of Asia.

GESTATION CRATES

In the conventional model of swine husbandry, we also see what is called a "gestation cage". "Nine out of 10 sows in America are kept in gestation crates, according to the National Pork Producers Council." Gestation crates are also used in Vietnam, as explained and photographed by Chetana Mirle of the Humane Society International (Farm Animal Welfare in Vietnam). If you want to see how sows are treated in gestation cages, take a look at this video. Canada has recently banned the use of gestation crates (Canada Bans Lifelong Pig Confinement amid Global Concerns, U.S. Pork Industry Urged to Follow Suit). Most of the biggest pork producers in the United States have pledged to stop using gestation crates within a few years (Christie's Pig-Crate Politics).

Bill Maher wrote a powerful and compelling article (Free Pigs from the Abusive Crates) against gestation crates:

WOULD you cram a dog into a crate for her entire life, never letting her out, until you took her to the pound to kill her? Of course you wouldn't, and yet that's effectively what happens to most mother pigs in this country. They spend their lives in what are called gestation crates, tiny stalls that house pregnant sows. They cannot even turn around, and are immobilized in these crates until they are taken to the slaughterhouse.

But banning the use of gestation crates and putting mated gilts and sows in groups does not go far enough. A hybrid sow is a large and heavy animal, and her feet should never come into contact with a concrete floor. Expectant females should be housed in groups on soft bedding where they are free to walk, run, exercise and interact with one another. We suggest that at least three square meters of bedding be allotted for each gestating female housed in groups. About two weeks prior to farrowing, they can be transferred to maternity pens where they can build nests and give birth in a natural manner.

At all stages in the conventional raising of pigs (piglets, grow-out pigs, gestating sows and farrowing sows), we see that cruelty is the norm. Furthermore, scientists are continuously trying to reinvent the farm animal, and here once again, cruelty is the norm. The experiments carried out on pigs, cows, sheep and other farm animals can be quite savage, as described in U.S. Research Lab Lets Livestock Suffer in Quest for Profit and Farming Science, Without the Conscience. "These experiments are not the work of a meat processor or rogue operation. They are conducted by a taxpayer-financed federal institution called the U.S. Meat Animal Research Center, a complex of laboratories and pastures that sprawls over 55 square miles in Clay Center, Nebraska." At the center, there was "a recurring failure to fully consider the pain that animals suffer during experiments, or in everyday life at the center." The parent agency of this animal research center is none other than the US Department of Agriculture. The pictures shown in both of these articles are disturbing.

OUTBREAKS OF BLUE-EAR AND SWINE FLU

When pigs are housed in large numbers and treated as nothing but products in an assembly line, their immune systems are highly compromised. Consequently the pig farmer in Vietnam has to contend with frequent outbreaks of viruses such as blue-ear and swine flu. The conventional pig farmer might borrow heavily from banks or loan sharks to cover the high cost of commercial feed and antibiotics. As pork prices decline, and as feed and antibiotic costs rise, he's lucky if he ends up with a profit margin of 10% or 12%. But if his pigs are hit with blue-ear or swine flu, all of his pigs are culled. Back in 2007 an estimated 45 million pigs died in China from blue ear.

Since the Vietnamese farmer has no private or state insurance, he constantly walks a thin line between marginal success and total failure. Large conglomerates such as Charoen Pokphand Foods of Thailand (now bought out by the Chinese) and Emivest of Malaysia insidiously move in, forcing him to minimize risk by growing pigs under contact (TPP: Getting US snout in Vietnam trough). He becomes a contractor instead of a farmer. "All industry insiders, from individual pig farmers to tycoons, say raising pig is similar to gambling: a lot of money is being invested – but it's unclear whether the money can be earned again" (Vietnam: Feed, sows and diseases make pig farming like gambling).

URBAN CHAOS

It's not surprising that the children of the Vietnamese pig farmer want nothing to do with the filth, inhumanity, risk and servitude associated with this way of life. They move to large cities to escape the poverty (and at times hunger) associated with rural Vietnam. There they typically live in slums, sometimes with as many as twelve people crammed into a one-room "apartment." Some try to send money back home to support their parents. At times ageing parents are neglected and left to fend for themselves. Social values that defined a culture for centuries are eroded. Small villages decline in population. Families are ripped apart. Air and water pollution in big cities become unbearable (HCM City air pollution causes major health problems and Polluted rivers, dwindling groundwater threaten Vietnam city supply).

According to a study by the HCMC-based Institute for Environment and Resources released last November, millions of people in HCMC and Binh Duong are using tap water from the Saigon and Dong Nai which are polluted by discharges from residential areas, hospitals, factories, waterway transport vessels, farms, and even garbage dumps.

On January 17, 2014, there was an outbreak of H1N1 within District 11 of Ho Chi Minh City. Todd Hyman (a co-author of this paper), together with his pregnant wife, was in district 11 at the time of this outbreak. A young niece living in the same house as Todd and his family contracted a severe case of swine flu. Everyone in this part of the city was in a state of total panic - urban chaos indeed.

Cases of H1N1 this year are increasing across Vietnam (Two Cases of H1N1 Virus Confirmed in Vietnam), and also all across the U.S and Canada (Another Pandemic? H1N1 Sweeping across U.S. and Canada in Deadly Wave). According to the famous virologist Robert G. Webster, pigs become "mixing vessels for the genes of avian, porcine and human forms of influenza" (The world is teetering on the edge of a pandemic that could kill a large fraction of the human population). Back in 2013, there was a virus outbreak in China that killed 16,000 pigs. These pigs were dumped in the tributaries of the Huangpu River, a source of Shanghai's tap water" (Empire of the Pig). We have no choice but to radically change the way we raise pigs.

Fermenting pig feed, removing fecal matter and spraying pig bedding with probiotics in the manner explained in this paper are three of the most powerful means of combating pathogens that infect pigs.

IS VIETNAMESE PORK FIT FOR HUMAN CONSUMPTION?

In the conventional pig pen, not only is the pig raised under the most dreadful conditions imaginable, but also most of the pork produced under such conditions is not fit for human consumption. Humans eat animals that lived their entire lives under the stress of filth, flies, disease and constant pain. Humans eat animals that were continually pumped with antibiotics so as to survive the filth, flies, disease and constant pain. In Vietnam "antibiotic residues in animal products were found to be tens to thousands of time higher than the international standard" (Study on Production of Safe Pig Meat with High Quality). A lot of Vietnamese pork, sometimes as much as 90%, does not meet microbial safety standards (Reducing disease risk and improving food safety in smallholder pig value chains in Vietnam). MRSA, Clostridium, E. coli and many other pathogens infest raw pork in Vietnam.

Then there are the high levels growth hormones found in Vietnamese pork, sometimes as much as 60 times above safe levels (Dangerous Levels of Growth Hormones Found in Vietnamese Pork). Police struggle to put an end to such abuse (Vietnam police confirm banned chemical used in rearing pigs). Even small pig farmers administer growth hormones in order to stay competitive.

What happens when Vietnamese children are injected with antibiotics (the fat drug) as often as children in industrialized countries? What happens when they eat pork or other meat products containing residues of antibiotics one hundred or one thousand times greater than international standards? What happens when Vietnamese children eat pork or other meat products containing growth hormones 20 or 30 times above safe limits? It's obvious that preschool children in Ho Chi Minh City are becoming overweight and obese (Vietnamese preschool children receive best care in the world?). No doubt the use of antibiotics and growth hormones plays a considerable role.

Closely linked with this are trends toward junk food and reliance on a small group of foods (Lower Diet Diversity Threatens Crops and Us). "Highly processed foods loaded with rapidly digesting carbohydrates" (another definition of junk food) are a big problem in weight control (Always Hungry? Here's Why). The US is already spending "an estimated $190 billion a year treating obesity-related conditions" (Michelle Obama on Attempts to Roll Back Healthy Reforms). Vietnam should avoid going down a similar path.

Even the highly controversial drug called ractopamine hydrochloride, a leanness and growth-promoting drug widely used in the US and Canada, has turned up in Vietnamese pork: "Police in southern Vietnam on March 23 said they had found traces of banned substances – ractopamine and salbutamol – in animal feed sold in Dong Nai Province, a major pork and pig supplier to Ho Chi Minh City" (Vietnam - Steroids found in pork). Ractopamine and other banned substances are "available in feed stores and veterinary drugstores for low prices, making it hard to control" (Police to help curb harmful feed agents). Also see: Vietnamese pig farms revert to illegal drugs and Vietnam police investigate hog farms amid drug overuse concerns.

"Fed to an estimated 60 to 80 percent of pigs in the US meat industry, ractopamime use has resulted in more reports of sickness or dead pigs than any other livestock drug on the market. According to FDA's own calculations, more pigs have been adversely affected by ractopamime than by any other animal drug – more than 160,000. Ractopamine's effects include toxicity and other exposure risks, such as behavioral changes and cardiovascular, musculoskeletal, reproductive and endocrine problems. It is associated with high stress levels in animals, "downer" or lame animals, hyperactivity, broken limbs and death" (Ractopamime Factsheet and Prefer Your Meat Drug-Free?). The European Union and over 90 other countries have banned ractopamime, since racto-meat has never been proven to be safe for humans, especially people with cardiovascular problems.

Imagine the scale of such brutality. Pigs that are already under enormous stress due to the horrible conditions under which they are raised are injected with ractopamime, a drug specifically designed to mimic stress hormones. Here we see a total disregard for the health and happiness of the pig.

If a Vietnamese farmer has a sick pig that does not respond to antibiotic treatment and is likely to die, he often rushes it off to market so as not to incur serious loss. Sometimes if a diseased pig dies before it can be brought to market, it is not destroyed or buried, but sold to traders: "Despite health risks to consumers, an experimental pig-breeding center operated by the US-based Cargill group in Dong Nai Province disposed of pigs that had died from illness by selling them to traders instead of destroying or burying them"(Cargill pig breeding center sells dead pigs to traders). Be sure and look at the photos of the dead pigs being sold for human consumption. In China the situation is far worse (In China, Stomachs Turn at News of 40-Year-Old Meat Peddled by Traders).

Not only is most conventional pork produced in Vietnam not fit for human consumption, but there are also other negative aspects that confront the consumer: it is produced at an unnecessarily high cost, and it tends to be watery, tasteless and full of fat. Dr. Hien Van Le conducted a boiling test on one kg of conventional pork and one kg of his unconventional pork. At the end of the test, the conventional pork weighed 30% less than his unconventional pork.

LARGE FUNDING ORGANIZATIONS NOT ADDRESSING CORE ISSUES

But it's not just feed, pharmaceutical and chemical companies that are to blame for this colossal mess with regard to the way pigs are being raised in Vietnam. Large funding organizations spend tens of millions of dollars each year in Vietnam, Laos and Cambodia, promoting the use of biodigesters. Many funding organizations, such as SNV, are based in industrialized countries where pigs for the most part are raised in the conventional way. Their intentions might be noble, but in convincing pig farmers in developing countries to use biodigesters, these organizations are implicitly endorsing the conventional model with concrete floors as best practice within the industry. The Vietnamese pig farmer concludes that if this is how things are done in Europe, the United States and China, then surely it must be right. Sadly, nothing could be further from the truth. Please read Everything You Didn't Want to Know About Hormel, Bacon, and Amputated Limbs. Here you will find a good description of how pigs are brutally raised and slaughtered in the United States. Also see this Undercover Video. The situation in China is even worse (Empire of the Pig).

Dr. Chetana Mirle of the Humane Society International visited a pig farm in Vietnam equipped with a typical biodigester (Farm Animal Welfare in Vietnam). On a farm with only 30 pigs, the biodigester that she saw provided cooking gas for 11 households. But take a good look at what she wrote – perfectly on target!

In order to facilitate manure capture, and to simply and efficiently transfer it to the biogas digester, the animals were continually confined to a barren, crowded, concrete enclosure, where they lacked the ability to move freely, let alone play, forage, or experience most other natural behaviors. I was deeply concerned to learn that these types of manure management projects are being actively promoted throughout Vietnam, despite the fact that there are more humane, effective, and sustainable means for managing animal waste, as well as mitigating animal agriculture's impacts on climate change. To add to my concerns, Vietnam's pig sector is also rapidly industrializing, and incorporating some of the most abuse intensive confinement practices in the animal agriculture sector.

It all boils down to this. Biodigesters do not solve the terrible problems associated with what happens within pig pens. If these problems would be solved, biodigesters would not be needed. In a situation that demands radical change, the installation of biodigesters does nothing to provoke radical change. Just about every aspect of conventional pig farming is deeply flawed, especially the use of concrete floors. Therefore, funding organizations should forcefully leverage money away from everything that is conventional. They should do everything possible to counter the rapid industrialization of pig farming in Vietnam and other developing countries. Some funding organizations go so far as to build conventional pig pens with concrete floors for poor farmers. Before the industrialized world attempts to help poor farmers in developing countries, it should first figure out how to clean up the mess it has created back home.

One cannot take the biodigester solution and apply it to the existing structure of industrialized pig farming, while leaving all aspects of industrialized pig farming "untouched and in place." This is not how sustainability works, as the award-winning writer, Dr. Tony Pereira, explains (Sustainability: An integral engineering design approach):

The general approach to sustainability is generally deeply flawed. Its main answer consists typically at throwing a perceived 'green' solution – e.g., wind, hydrogen, biomass, nuclear or solar energy – to real world problems – water, waste, food or energy – in one single plug-in format to existing systems, while leaving all other existing issues associated with the un-sustainable existing structures untouched and in place.

THE APPLICATION OF THESE CONCEPTS IN THE INDUSTRIALIZED WORLD

We believe that most of the technologies and strategies described in this essay could be adapted and applied on pig farms in the industrialized world. More space per pig would be needed. But this cost would be immediately offset by huge reductions in disease and mortality. Dr. Hien Van Le has already developed mixing equipment needed for fermenting large batches of feed.

A conventional pen would require little modification with respect to the use of bedding. The height of the wall of the pen might have to be increased. Bedding can be laid down on existing concrete floors. Wheat straw is abundant in Europe and the US, and it could be easily cut to a short length to serve as bedding. To save time, fine bedding could be brought in and laid down by means of an air transport system. Probiotics could be automatically misted onto pigs and bedding by means of an overhead misting system.

Imagine the money that could be saved in temperate climates during winter time if pigs were to be housed on bedding rather than on concrete floors. The cost of heating a pig pen in winter time would drop significantly. "For example, in a building with no drafts, a 200 lb pig with deep bedding will experience the same thermal conditions at an air temperature of 55 ºF as the same pig would at an air temperature of 78 ºF if kept on a wet, solid concrete floor" (Environmental Needs of the Pig). Since there are no ammonia emissions from bedding, the cost of ventilation and air exchange would be greatly reduced.

Urban farmers in the industrialized world do great things in growing fruit and vegetables in unconventional places ('Agrihoods' Offer Suburban Living Built Around Community Farms, Not Golf Courses). They admirably de-industrialize the process of growing food. Generally consumers know that what they are eating is fresh and safe, and consumers, in many cases, can buy directly from farmers. With urban agriculture, permeable surface for storm water management is increased. The heat island effect is reduced. Packaging, processing and transport costs are reduced. Far less produce spoils on its way to the consumer. People are reconnected to nature. And the local economy benefits enormously.

No doubt, Japan leads the industrialized world in urban agriculture. One third of all agricultural output in Japan is generated by urban agriculture, and 25% of farming households in Japan are located in urban areas. A fairly recent study reveals that 85% of Tokyo residents want their city to have farmland (Japan's Urban Agriculture: Cultivating Sustainability and Well-being). The Japanese, with their deep reverence for nature, have no problem understanding that urban farms create a "bundle of ecosystem services for human well-being." Urban agriculture in Japan does not represent a loss in productivity, as some might think. In fact, it "is more productive than its rural counterparts."

But not many urban agriculturalists realize that pigs could be grown in or near cities. When odor is completely eliminated by means of bedding, and when there is no dirty and voluminous effluent to deal with, pigs can be raised just about anywhere. A vacant city lot would be a great place to raise pigs. Pigs can perform two very important services in an urban setting: they can dispose of food waste, and through the transformation of their own waste, they can provide feed and fertilizer to the urban farmer. The transport of waste, feed, fertilizer and food is minimized. The radius of the sustainability loop shrinks to almost nothing.

The fact that pigs are raised in or near cities has another advantage. Normally when people see happy and healthy pigs at play on bedding, they view pork in an entirely different way. Some are filled with a sense of reverence, gratitude and apology. Others become vegetarian.

NOT INHUMANE CONFINEMENT AND NOT FREE-RANGE

Some in the United States advocate raising pigs outdoors (Demand Grows for Hogs That are Raised Humanely Outdoors). In developing countries such as Vietnam where land is in short supply, raising pig outdoors is not feasible. It's hard to access and valorize pig waste that is scattered over a broad area, and excessive nutrients can build up in soil and water. "The cruelties of intensive indoor production" should not be replaced by "the wreckage of extensive outdoor production," as George Monbiot phrases it (Warning). He further explains:

Free-range pig and chicken farming, practiced on the current scale, can be environmentally disastrous. Nitrates and phosphates sometimes pour from their paddocks and into the rivers. Unless they are kept at low densities or on well-drained fields, pigs tend to mash the soil: a friend describes some of the farming he's seen as opencast pig mining.

Pigs are smart. They're experts in breaking out of fenced areas. Feral pigs cause about $1.5 billion in damage to crops and the environment each year in the U.S. (Feral Pigs Creating More Problems Locally, Statewide, Can Wild Pigs Ravaging the U.S. Be Stopped? And Who Can Stop these Adorable Pigs). In many places extreme weather events of hot and cold make it difficult to raise pigs outdoors. Then there are problems with bare ground, soil compaction and excessive wallows. The problem back in the 1950's was not that pigs were brought indoors, but that they were brought indoors, put on concrete floors, raised under the filthiest of conditions and pumped with antibiotics.

Instead of inhumane confinement or free-range, we suggest a third way: *confinement in a spacious, clean and odorless setting that accords comfort and dignity to animals.* If humans are going to eat pork, at the very least they should make sure that the pig does not suffer and that all of its basic needs are met. One does not have to be vegetarian or vegan to understand the simple moral imperative that all humans should hold sacred: one should never eat meat derived from an animal subjected to misery and pain. At every point in its short life, the pig should lead a happy and healthy life (The Enigma of Animal Suffering). It should be raised in a setting that closely resembles what happens in nature.

Pigs in a natural setting walk and run primarily on soft dirt. As they run, play and get plenty of exercise, they stay lean and fit. They spend a great deal of time rooting through the forest floor. They forage for larvae, worms and other edibles within the soil. They do not eat out of troughs. They eat a lot of dirt that contains lactic acid bacteria and other beneficial microbes. This dirt usually contains an abundance of earthworm castings. If it gets hot, pigs sleep during the day and become crepuscular and nocturnal. In a natural setting, pigs do not come into contact with their feces. Nor do they suffer from the emission of ammonia from urine. Gestating sows in a natural setting live in groups and are able to get plenty of exercise. When it's time to farrow, they build nests. Their piglets also engage in nest-build activity. Piglets are not prematurely weaned, and they transition to solid food in a gradual manner. Since sexually immature male pigs in the wild remain entire, they vie for dominance and playfully mount females.

In this unconventional way of raising pigs, most of the physiological and behavioral needs of the pig are met. Even the combined activity of BSF larvae and red worms closely matches what happens in nature as red worms and earthworms often feed upon larval residue and leave behind a vermicompost that no fertilizer company could ever engineer (Earthworms Vermicompost). If putrescent waste accumulates in a tropical or sub-tropical setting, eventually BSF larvae drive out all other species of larvae. Yet they never disturb worms feeding off their residue below.

BROILER CHICKENS ON FACTORY FARMS

The unconventional approach to raising pigs outlined in this essay can also be adapted to raising chickens. Change is as desperately needed here as in the raising of pigs. Chickens on factory farms lead miserable lives under absolutely horrendous conditions (see Truth Matters: DxE Investigators Expose "Humane" Fraud at Whole Foods). "But less well-known is the fact that the core problem for these birds starts long before they are even born: in effect, these birds are bred to suffer" (A Growing Problem). Also see Nicholas Kristof's summary of the problem (The Unhealthy Meat Market).

Today's broiler chickens, conventionally known as the "Cornish cross," grow at a rate three times faster than chickens grown in 1960. They have disproportionately huge and distorted bodies. At just a few weeks old, they are barely able to move. On the outside they are big and muscular, but in the inside their skeletons and organs are grossly undersized. "Their hearts, lungs and legs strain to work under severe pressure, causing severely low stamina, shortness of breath, trouble standing and walking, collapse and even congestive heart failure." Their leg bones, tendons and joints develop improperly, and they rapidly degenerate or give way, "causing pain and debilitation."

Since it is difficult for these chickens to stand, they spend up to 90% of their time lying down on the floor of the pen which, of course, is anything but clean. As they lie down, they get eye and respiratory infections from high concentrations of ammonia gas. As they lie down on ammonia-soaked litter, they develop lesions. These lesions make it even harder for them to move, and of course these lesions get easily infected. Open sores develop on their feet, legs and chest. "These wounds may become deep ulcers that can further develop into abscesses." Those parts of the leg that come into contact with litter are typically full of "hock burns." With under-sized hearts and lungs, these chickens contract congestive heart failure, pulmonary arterial hypertension (Pulmonary arterial hypertension in broilers: A review), the "Green Muscle Disease," and the "Sudden Death Syndrome." The Sudden Death Syndrome can occur in the first week of the life of the chicken.

Chickens that are not yet lame walk like obese humans. These chickens often spend "the final portion of their lives lying in their own waste, unwilling or unable to walk even a few steps." Not able to reach food or water, many die from starvation or dehydration. Lameness is "the leading cause of mortality." The same euphemistic term used to describe the leg condition of pigs is also used to describe the leg condition of chickens – "leg weakness." Chickens live under extreme stress and pain. Without antibiotics, they assuredly could not survive. Their immune systems are virtually non-functional, and they are incredibly easy targets for bird flu and other viral infections. At an age of just a few weeks, these super-size chickens are brought to slaughter.

This is the quality of broiler meat that most Americans consume, and they consume it at a colossal rate of nine billion broilers per year. Kentucky Fried Chicken alone dishes out roughly one billion birds. KFC in China faced big problems when in late 2012 "excessive amounts of antibiotics and hormones [were] discovered in some chicken products" (Food Safety in China Still Faces Big Hurdles). KFC has recently set up outlets in Ho Chi Minh City and Hanoi (Foodpanda, KFC continue expansion in Vietnam). The Vietnamese people should not be eating such disgusting meat.

The production of broilers in the US is controlled by just 40 integrators. Three integrators control half of all the chicken Americans eat (The Meat Racket). These companies control the parent stock from which these super-size birds are bred. But here they face a dilemma. They must breed birds that grow fast, but if the parents of these birds grow equally fast, they will collapse under their own weight and will not be able to lay eggs. It takes 5 to 7 weeks before a hen can lay eggs, but if the hen is grossly oversized in just a few weeks, she cannot lay. To solve this problem, hens are deliberately starved. They are given only a small fraction of the food and water what they would normally require. "This is an extreme form of cruelty."

Throughout the world, most factory farms raise chickens in exactly the same way. You've got to see the pictures of chickens shown in *A Growing Problem* to understand what misery humans inflict on poultry. Particularly disturbing is that picture of the "Green Muscle Disease." If you want to see how chickens are brutally raised and slaughtered on factory farms, watch video and video.

Then there are many human health problems associated with the factory farming of chickens.

Arsenic is extremely toxic and causes cancer even at relatively low levels. "Arsenic also contributes to other diseases, including heart disease, diabetes and declines in intellectual function, the evidence suggests" (Playing Chicken: Avoiding Arsenic in Your Meat). As dangerous as arsenic is known to be, arsenic has been intentionally added to chicken feed for many decades. "Of the 8.7 billion American broiler chickens produced each year, estimates are that at least 70 percent have been fed arsenic. Some of that arsenic stays in chicken meat." Arsenic also contaminates much of the 25 million metric tons of chicken litter or waste generated by the broiler industry in the United States. Some of this toxic litter is fed to cattle. Some is used to fertilize fields and pastures.

Chicken litter can be heavily infected with MRSA, and flies love chicken droppings. When flies come into contact with chicken droppings, they spread MRSA and other pathogens to humans (Study: Flies Spreading MRSA From Chicken Droppings). As many as many as 30,000 flies can fly in and out of a poultry house over six weeks, and these flies travel large distances. When they enter houses and regurgitate chicken droppings onto human food, humans are at grave risk.

There are antibiotic resistant E. coli. “Poultry workers in the United States are 32 times more likely to carry E. coli bacteria resistant to the commonly used antibiotic, gentamicin, than others outside the poultry industry, according to a recent study conducted by researchers at the Johns Hopkins Bloomberg School of Public Health” (Poultry Workers at Increased Risk of Carrying Antibiotic-Resistant E. coli).

There are antibiotic resistant Salmonella strains: “The number of antimicrobial-resistant Salmonella serotypes hasn’t increased drastically in recent years, but drug-resistant Salmonella continues to pose a public health threat in the United States, particularly as resistance spreads across classes of drugs, necessitates the use of more expensive drugs, makes treatment less effective, and, in worse-case scenarios, leaves infections untreatable” (Emerging Pathogens: Antibiotic Resistance Slowly Growing in Salmonella). “A salmonella outbreak in Foster Farms contains several antibiotic-resistant strains that may explain an unusually high rate of hospitalization” (Salmonella outbreak in chicken shows resistance to antibiotics).

Antibiotic resistance is also found in Campylobacter: “Campylobacter is a leading foodborne bacterial pathogen, which causes gastroenteritis in humans. This pathogenic organism is increasingly resistant to antibiotics, especially fluoroquinolones and macrolides, which are the most frequently used antimicrobials for the treatment of campylobacteriosis when clinical therapy is warranted” (Antibiotic resistance in Campylobacter: emergence, transmission and persistence). Also in this regard see Widespread acquisition of antimicrobial resistance among Campylobacter isolates from UK retail poultry and evidence for clonal expansion of resistant lineages.

Some slaughtering facilities in the US kill as many as 170 chickens per minute. During the slaughtering process, huge quantities of antimicrobial sprays are needed to disinfect chickens of E. coli, Salmonella, Campylobacter and other pathogens. The workers and USDA inspectors who are exposed to these toxic chemicals end up with serious problems such burns, rashes, irritated eyes, sinus ulcers and severe respiratory problems (Chicken Nuggets, With a Side of Respiratory Distress). Also, in killing so many birds per minute, many workers are afflicted with a painful condition called carpel tunnel syndrome. It’s all about killing chickens as fast as possible in order to maximize profits.

RAISING CHICKENS INDOORS

Obviously we must raise chickens that are bred to grow at a more natural rate. But we must go on to do a whole lot more. First of all, we recommend that that all chicken feed be fermented (Potential of Bacterial Fermentation as a Biosafe Method of Improving Feeds for Pigs and Poultry). Lactic acid gives chicken feed powerful anti-microbial activity. It knocks out Salmonella, Campylobacter and coliforms within chicken feed. With lactic acid fermentation, the chicken has access to a lot more nutrients, and feed consumption is significantly reduced (Fermented Feed).

Dr. Hargis of the University of Arkansas conducted trials that demonstrate the importance of probiotics fed to broiler chicks shortly after hatching (Hatchery-applied probiotics can improve broiler performance). He maintains that probiotics should be applied in the hatchery before the chick is exposed to pathogens in the broiler house.

The intestinal microbiota of the chicken can aid the health and growth of the bird by fermenting carbohydrates, producing short-chain fatty acids, metabolizing proteins, and enhancing mineral and lipid absorption. Early establishment of the intestinal microbiota promotes proliferation and differentiation of epithelial cell lineages, regulates angiogenesis, modifies the activity of the enteric nervous system, extracting and processing nutrients in the diet, assembly of the gut-associated lymphoid tissue, and education of the immune system.

But why administer probiotics as a feed additive or supplement? Why not ferment most feed? And if we are going to ferment chick feed, why not continue to ferment throughout the entire grow-out period of the broiler?

Ensiled duckweed makes an excellent feed for chickens. We should not overlook the importance of fermented perennial peanut in the diet of chickens. Fish waste can be fermented and fed to chickens (Characterization of fermented fish waste used in feeding trials with broilers). Food waste can be fermented in Japanese mugwort silage juice and fed to chickens (Utilization of Eco-Feed Containing Mugwort Microorganism Compounds as a Feed Ingredient Source for Layer Hens). It's quite amazing to see the huge bundles of parasitic round worms excreted by chickens the first time they eat fermented banana stem.

Fermented chicken feed can be enriched with a small amount of biochar (Biochar in Poultry Farming). When biochar is added to the fermentation mix, chicken droppings emit much less ammonia and do not smell. With biochar the incidence of foot pad and diarrheal diseases is minimized. The health of the chicken improves, along with increased meat and egg production. According to studies by Van (2006), less than 1% biochar in chicken feed improves growth in young chickens by an average of 17%.

We suggest that chickens should not be allowed to free-range outdoors. In Vietnam chickens should remain indoors where they are not easily stolen and where farmers can efficiently access and valorize their waste. Approximately 60 to 70% of the chickens sold in Vietnam are free-range (A General Review and a Description of the Poultry Production in Vietnam), and sadly a lot of their waste does not make it back to agriculture, even in the form of compost. There is no systematic collection of chicken droppings in an outdoor setting. When it rains, most of these valuable nutrients pollute streams and rivers.

Thirty to forty per cent of the chickens raised in Vietnam are housed indoors on semi-industrial and industrial factory farms. Charoen Pokphand Foods of Thailand owns half of the industrial poultry operations in Vietnam. This conglomerate grows broilers on factory farms in the same deplorable manner as in America. One should not be surprised by the fact that "CP is present in nearly every country where bird flu has broken out" (A Fowl Plague). The fight against bird flu must be not waged in the "backyard of the world's poor," but right at the gate of the factory farm where chickens are raised in the most cruel and unsanitary manner imaginable.

But if chickens are housed indoors, they should be housed on fine, dry biomass bedding enriched with biochar. At least one square meter of bedding should be allotted for every three chickens. Why so much space? The answer is simple. Chickens should be able to do all of the things that they would normally do in a natural setting. They need space to preen, run, flap, scratch, jump, dust-bathe, peck and stretch. They should also be given the opportunity to scratch and search for live larvae and worms as they would in a natural setting. Chickens need to establish a pecking order.

They are social and intelligent. They need plenty of space to interact with one another. With a lot of activity and social interaction, chickens stay entertained, healthy and fit.

One might rake chicken droppings off bedding at least once each day and feed to BSF larvae. Larval residue in turn can be fed to red worms. The bedding should be sprayed at least once a day with a probiotic liquid. Live larvae and red worms grown on fresh chicken manure make an excellent feed for pigs, especially young pigs.

Also one might ferment fresh chicken droppings along with rice bran, cassava root meal or residue, and molasses. This fermented mixture can then be fed to pigs, as explained in Ensiling and preserving chicken manure as animal feed and its evaluation in diets of F1 fattening pigs under village conditions. Fresh chicken droppings can comprise up to 40% of the fermentation mix. Older pigs faired quite well on this diet - younger pigs less so. The fermented mixture can be stored for at least 90 days. After 14 days of fermentation, all E. coli and Salmonella were destroyed. Sweet potato vines can also be fermented along with fresh chicken manure and fed to pigs (Nguyen Thi Tinh and Tran Thanh Thuy 2000). Fresh chicken manure can be fermented and fed to tilapia; Impact of using raw or fermented manure as fish feed on microbial quality of water and fish. Also see: Some Microbiological and Chemical Properties of Poultry Wastes Manure After Lactic Acid Fermentation. Fresh chicken manure can be fermented together with chopped rice straw bedding and fed to cattle (more on this in the section on intensive agriculture).

Chicken droppings, therefore, are far too valuable to let go to waste within litter, especially if fresh droppings can be fermented or used to grow larvae. BSF larvae have no problem whatsoever eating fresh chicken droppings. In developing countries such as Vietnam where labor is not expensive, each day farmers can rake fresh chicken droppings off bedding. In developed countries, chicken droppings could be vacuumed or raked off bedding with a special self-propelled machine designed specifically for this purpose. The fact that some bedding is raked or vacuumed along with chicken droppings does not pose a problem either in the case of fermentation or larval bioconversion.

The key to combating pathogenic bacteria and viruses within the poultry industry lies in three powerful strategies: fermenting all chicken feed, removing fecal matter on a daily basis, and sanitizing bedding with probiotics on a daily basis. When chickens eat unfermented feed, when they are in constant contact with their waste, when they inhale ammonia in high concentrations, when they are infested with filth-bearing flies and when antibiotics are added to their feed, their immune systems are highly compromised. It should come as no surprise that they easily catch avian flu.

In the first eight weeks of 2014, Vietnam has reported 36 outbreaks of H5N1 to the World Organization for Animal Health. In 2015 news cases of avian flu in Vietnam are continually being reported (Latest Avian/Bird Flue News). In March 2015, cases of avian flu have been reported in Lam Dong province (33 avian flu cases found in Lam Dong and Influenza A H1N1 outbreak confirmed in central Vietnam.

The situation now in the United States is totally out of control (Egg Farms Hit Hard as Bird Flu Affects Millions of Hens). “Almost every day brings confirmation by the Agriculture Department that at least another hundred thousand or so birds must be destroyed; some days, the number exceeds several million.” If Vietnam needs a model of how not to raise chickens, it has only to turn to the United States. The poultry industry there is in complete shambles and must be radically overhauled.

THE BATTERY CAGE FOR LAYING HENS

Perhaps the cruelest form of factory farming is the battery cage for laying hens (The Cruelest of All Factory Farm Products: Eggs From Caged Hens). About 95% of all eggs produced in the US come from caged hens. Here each hen is allotted a space of less than 0.043 square meters. This equates to more than 23 hens per square meter. "To get a sense of a hen's life in a battery cage, imagine spending your entire life in a wire cage the size of your bathtub with four other people. You wouldn't be able to move, so your muscles and bones would deteriorate. Your feet would become lacerated. You would go insane. That's precisely what happens to laying hens."

All of the natural instincts of the hen are suppressed, and as a result caged layers resort to pecking, bullying and cannibalism. "In an attempt to prevent this behavior from causing injuries, factory farmers routinely conduct beak-trimming or 'de-beaking' on chicks. This involves the practical removal or burning off of the upper and lower beak through the application of an electrically heated blade" (Battery Hens). Such cruelty should be condemned and prosecuted as criminal. Poultry cages are hot-selling items in Vietnam (Poultry cages for layer chicken hot sell in Vietnam).

On December 31, 2014, Proposition 2 took effect in California (Hens, Unbound). It requires that birds have enough room to freely spread their wings unimpeded by cage walls or other chickens. Some interpret this to be as much as 0.129 square meters per hen or about 7.75 birds per square meter. Even this is far too little space. We recommend no more than three hens per square meter.

The incineration or gasification of chicken litter, as many advocate, is far from being an optimal solution. Once again nutrient-rich Type 2 waste should not be processed as low-grade Type 4 waste.

Chickens, like pigs, are great disposers of food waste, and urban farmers can take full advantage of their ability to scavenge. Their waste is golden, and the urban farmer can transform it into feed and fertilizer. The radius of the sustainability loop shrinks even further.

COWS NEVER ON CONCRETE

This unconventional approach can be extended to raising cows. Due to the shortage of pastureland, many cows in Vietnam are permanently housed indoors. Farmers cut and carry many types of grasses, transport these grasses on motorbikes and feed them to cows housed in barns and sheds. Turning grasses into meat and milk makes a lot of sense. But unfortunately most cows raised indoors in Vietnam are tethered in confined spaces on hard concrete floors.

Due in part to the dirty conditions under which the cows are raised, subclinical mastitis is prevalent in Vietnam (Prevalence of subclinical mastitis and isolated udder pathogens in dairy cows in Southern Vietnam). "The results indicate pronounced subclinical mastitis problems among the dairy cows in this region mainly due to infections with S. agalactiae." When a cow contracts mastitis, the udders swell and develop bloody lesions. Quite often pus ends up in milk. To combat S. agalactiae, farmers administer antibiotics in heavy doses.

We suggest that if cows are raised indoors, they should not be tethered or harnessed, and of course, they should never be placed on concrete floors or any other hard surfaces. Concrete floors are not only dirty, unsanitary and covered with biofilm, but they are also quite uncomfortable for the cow. They cause cows to stand more than they would normally do. If cows do not lie down enough, they have poor circulation in their feet. Hard floors increase the risk of subclinical laminitis (Causes, Risk Factors, and Prevention of Laminitis and Related Claw Lesions).

Concrete floors restrict movement and put cows under a great deal of stress. Cows often slip on concrete floors. Some recommend the use of rubber mats to prevent slippage. But rubber mats do not effectively solve problems relating to hoof disorders, skin lesions, the dirtiness of the animals and ammonia gas concentration (Changes in hoof health and animal hygiene in a dairy herd after covering concrete slatted floor with slatted rubber mats: a case study).

A dairy cow might lie down and get up about 16 times a day. As she lies down, about two thirds of her weight transfers to her front knees. Her knees then freely drop to the floor from a height of 20 to 30 cm's. Over the course of a year, a cow might lie down and get about 6,000 times. If her knees repeatedly hit concrete or some other hard surface, her skin, knees, bones and joints get severely damaged. She easily becomes lame.

Instead of concrete floors or rubber mats on concrete floors, we recommend that cows be housed on soft bedding of a depth of at least 60 cm. At least 12 square meters of bedding should be allotted per cow. Preferably each cow should be housed in its own pen, separate from other cows. When cows are confined to individual pens, the farmer has better control over diet, health and the spread of disease. And cows do not trample on each other's manure.

The bedding might consist of finely cut and fully dry rice straw together with 20% rice hulls and 5% rice hull biochar by volume. "With a comfortable environment, dairy cows will lie down 12 to 15 hours a day and most often when ruminating. Comfortable stalls mean soft bedding and enough space for rising and lying down." When a cow lies down, blood circulation to the udder increases by up to 30% (Cow Comfort).

The bedding for the cow should be sprayed once a day with a probiotic liquid. No effort should be made to limit bacterial growth by means of conventional anti-bacterial sprays, since beneficial bacteria within probiotic sprays predominate and keep pathogens in check. Spraying the feet, knees and udders with probiotics is especially important.

The urine of the cow drains into the bedding and is absorbed by it. There nutrients in cow urine get quickly sorbed or converted into microbial biomass. There is virtually no ammonia, nitrous oxide or methane escape from bedding. Each day the farmer should rake wet spots within the bedding and make sure that the bedding stays uniformly dry. Once a day, fresh manure should be transferred from the bedding to nearby bins or biopods to be devoured within hours by hungry BSF larvae. When these bins or pods fill up with residue, their contents can be brought to a vermicomposting facility.

In this bedding concept, the urine and feces of the cow do not mix. Simply not mixing the two reduces ammonia emissions. "It should be noted that urine and fecal material, individually, emit minimal amounts of ammonia; it is the physical process of combining urine and feces after deposition on a floor surface, which results in ammonia volatilization in dairy housing" (NITROGEN FROM THE FARM TO THE ENVIRONMENT).

For a variety of reasons, cows living outdoors eat dirt, and when brought indoors, it's likely that they too, like pigs, will eat bedding, provided of course that manure is removed from off the bedding and that the bedding is sprayed daily with probiotic liquids. Cows obviously are much better equipped than pigs to digest bedding. A lot of the nitrogen and other nutrients excreted by the cow are in the form of urine, and to immediately return these nutrients back to the cow might transform the economics of bovine husbandry wherever cows are housed indoors. To induce cows to eat bedding, fermented feed could be made available to cows on bedding.

When cows are raised indoors in Vietnam, this bedding concept fully addresses issues relating to mastitis, laminitis and many other bovine health problems. Antibiotics are not needed. A milk cow raised under the proper conditions should be able to achieve more than eight lactations without a significant loss in milk productivity. The reasoning here is simple. If cows are not sick and in pain, and if they are comfortable and free of stress, they produce on average more milk over a longer period of time.

In Vietnam cows are generally culled after only five lactations (Dairying in Vietnam), and when they are slaughtered, nearly 40 percent of dairy cows are lame (Cows Used for Their Milk). Dreadful, absolutely dreadful! If you want to get a sense of how dairy cows and their calves are treated on factory farms in America, watch this video: The Disgusting Treatment of Cows and their Calves. Large dairy farms (one with as many as 30,000 cows) already exist in Vietnam.

Many farmers in Vietnam have recognized the fertilizer value of cow manure. At times cow feces is transported relatively long distances to be used in growing vegetables. But using manure from cows raised in the conventional way poses serious problems. Because antibiotics are administered to cows, it has been recently discovered that cow manure harbors diverse new antibiotic resistant genes. "Manure from dairy cows, which is commonly used as a farm soil fertilizer, contains a surprising number of newly identified antibiotic resistance genes from the cows' gut bacteria. The findings, reported in mBio® the online open-access journal of the American Society for Microbiology, hints that cow manure is a potential source of new types of antibiotic resistance genes that transfer to bacteria in the soils where food is grown" (Cow Manure Harbors Diverse New Antibiotic Resistance Genes).

In another study, we see that when antibiotics are administered to cows, its microbiome becomes a reservoir of antibiotic resistant genes. "Previous studies have focused on antibiotic resistance genes in manures of animals subjected to intensive antibiotic use, such as pigs and chickens. Cow manure has received less attention, although it is commonly used in crop production. Here, we report the discovery of novel and diverse antibiotic resistance genes in the cow microbiome, demonstrating that it is a significant reservoir of antibiotic resistance genes" (Diverse Antibiotic Resistance Genes in Dairy Cow Manure).

In these two studies, we see that it's not safe to be handling the manure of cows that receive antibiotics, and it's not safe to be using their manure to fertilize crops. If cows are raised on soft bedding under clean and sanitary conditions, antibiotics are not needed, and consequently their manure becomes a valuable resource and not a dangerous pollutant. More to come further on in this paper about the advantages of housing cows indoors.

MONSANTO AND THE RECOMBINANT BOVINE GROWTH HORMONE

A recombinant bovine growth hormone (rBGH or rBST), a genetically modified product made by Monsanto, is widely used to get cows to produce more milk. But there are some 20 adverse side effects associated with the use of this drug (rBGH in Milk). It causes a 79% increase in mastitis, and to combat mastitis due to rBGH, farmers increase the use of antibiotics, sometimes by as much as

100 times. rBGH causes weight loss in cows: they cannot eat enough to keep up with milk production. It causes aberrations of the reproductive system. Cows give birth to dead and grossly deformed calves. It also increases foot disorders in cows.

rBGH increases milk production through the stimulation of another growth hormone called IGF-1. IGF-1 ends up at elevated levels in milk, and it is readily absorbed into the bloodstream by humans. "IGF-1 is a naturally occurring potent growth hormone and cell death inhibitor that has been implicated in breast, colon, and prostate cancer as well as abnormal cell growth." There is a clear connection between IGF-1 and cancer (Milk and the Cancer Connection), including lung cancer (THOSE WHO SPEAK, HEAR, AND SEE EVIL). "Levels of insulin-like growth factor-1 (IGF-1) are substantially elevated and more bioactive in the milk of cows hyper-stimulated with the biosynthetic bovine growth hormones rBGH, and are further increased by pasteurization" (Unlabeled milk from cows treated with biosynthetic growth hormones: a case of regulatory abdication). One hundred and one countries have banned rBGH milk (American Milk Banned).

Should Monsanto, the creator of Agent Orange, glyphosate, rGBH, saccharin, DDT and many other dangerous products, be allowed to do business in Vietnam (Monsanto's Dirty Dozen and Monsanto tops the list of top 10 homicidal corporations)?

MITIGATING THE PRODUCTION OF ENTERIC METHANE

"Globally, ruminant livestock emit about 80 million metric tons of methane annually, accounting for 28 percent of global methane emissions from human-related activities" (Enteric Fermentation Mitigation). Methane traps heat within the atmosphere about 25 times more effectively than carbon dioxide. Methane is also an important precursor of tropospheric ozone. Therefore, reducing the production of enteric methane from beef and dairy cows has to be a top priority.

One way of reducing the production of enteric methane is to shred and ferment the feed of the cow. An easy way to ensile is by means of Effective Microorganisms (EM-Silage). With EM fermentation, "in-vitro studies showed a significant increase of proprionic acid and decrease in the production of acetic acid and methane gas. The change in the VFA composition and reduction of methane in the rumen are beneficial to both the cow and the environment." Grass ensiled with EM is "worth on average an extra one liter milk per cow per day."

In a truly amazing study (Biochar reduces enteric methane and improves growth and feed conversion in local "Yellow" cattle fed cassava root chips and fresh cassava foliage), we see that "live weight gain [of cattle] was increased 25% by adding 0.62% biochar to the diet DM and tended to be decreased when nitrate replaced urea as the source of NPN." As more feed is converted into animal body mass, it makes sense that less methane is produced. In this study we see that the reduction in enteric methane is quite astounding: "Biochar and nitrate reduced methane production by 22 and 29%, respectively, the effects being additive (41% reduction) for the combination of the two additives." The biochar used in this study was rice hull biochar produced in the simple top-lit, updraft gasifier explained earlier in this paper.

Mixing biochar into a fermentation mix makes it easy to incorporate biochar into the diet of the cow. Furthermore, Vietnam has over 10,000 hectares of neem trees, and mixing neem cake into fermented feed (prior to fermentation) also helps in the mitigation of enteric methane (see Methanogenesis and recent techniques for mitigation of methanogenesis in ruminants). Fats and oils can reduce enteric methane. Cottonseed can reduce methane by 12% and sunflower oil by 22%. Coconut and palm oil are also helpful in this regard.

Forage quality has a significant impact on enteric methane emissions. “Inclusion of legume-based forages in the diet is associated with higher digestibility and faster rate of passage resulting in a shift toward high propionate in the rumen and reduced methane production” (STRATEGIES FOR REDUCING ENTERIC METHANE EMISSIONS IN FORAGE-BASED BEEF PRODUCTION SYSTEMS). Supplementing the diet of cattle with certain minerals can also reduce methane production. There are many other ways to reduce the production of enteric methane (Reducing methane emissions from cattle using feed additives). But one thing is clear: the diet of the cow must be strictly controlled. More on this a bit further on.

Most people do not have a problem understanding that when a cow produces enteric methane, this usually represents an inefficiency in meat or milk production. Yet these same people do not always understand that when a biodigester produces methane from putrescent waste, this also represents inefficiency. Instead of fermented feed, or feed in the form of larvae and red worms, or fertilizer in the form of larval frass or vermicompost, one ends up with methane. When this methane is burned, it escapes the food/feed/fertilizer loop and is completely lost to agriculture.

While some people make methane out of putrescent waste that could be easily converted into feed and fertilizer, others go in the opposite direction and make feed and fertilizer out of methane, more precisely, out of natural gas. Yes, even feed can be produced from natural gas: “Carbohydrates, amino acids, lipids and other vitamins can be produced from methane, as well as other key compounds to improve the health and quality of livestock” (Calysta Acquires BioProtein; Proven Methane to Feed Technology). This natural gas-to-feed conversion technology is misguidedly touted as being sustainable. The fact that feed and fertilizer can be produced out of methane constitutes a strong argument against generating methane out of putrescent waste and burning it.

FERMENTING RICE STRAW AND COFFEE PULP FOR COWS

When harvested at full ripening stage while the stems are still green, rice straw has a high moisture and nutrient content. It can be converted into high quality silage for cattle (Effects of treating whole-plant or chopped rice straw silage with different levels of lactic acid bacteria on silage fermentation and nutritive value for lactating Holsteins).

In this study best results were achieved when the LAB inoculants were added to the fermentation mix and when the rice straw was chopped. About 5% molasses should be added to the fermentation mix (Improving the nutritive value of ensiled green rice straw 1-Fermentation characteristics and chemical composition). We suggest further that less than 1% rice hull biochar (DM basis) be added. Fresh chicken manure can be added, as previously explained.

If rice is grown intensively as in the System of Rice Intensification, much less water is used in growing rice. As the rice plant matures, it does not prematurely die due to flooding. This gives the farmer more opportunity to harvest rice straw while still green. More on SRI in the section on intensive agriculture.

In the highland areas of Vietnam where rice is not grown, coffee pulp can be fermented and fed to cows. “The reported literature showed that coffee pulp can replace up to 20% of commercial concentrates in dairy cattle feeding, with no adverse effects and a 30% cost savings” (Potential alternative use of coffee wastes and by-products). The tannins in coffee pulp also help to mitigate the production of enteric methane. "Other benefits associated with feeding condensed tannins in ruminant diets include reduced incidence of bloat and intestinal worm populations."

THE PERENNIAL PEANUT FOR COWS AND THE IMPORT OF POWDERED MILK

Perhaps the best forage for a cow in a tropical setting is the perennial peanut. In the United States, it is often referred to as the "alfalfa of the south" (The Alfalfa of the South). In this paper (Perennial Peanut: Forage Nutritional Composition and Feeding Value), we see that for ruminant animals, the "perennial peanut is very nutritious and well liked. The nutritional quality of perennial peanut appears to be as good as alfalfa." A bit further we read, "Perennial peanut is very nutritious and in most cases has more nutrition than what is needed by the animal." Unlike many other legumes, the perennial peanut does not cause bloating. Since the perennial peanut does not grow well in the last two months of dry season, it can be ensiled and stored for feeding throughout the year.

The perennial peanut is well accepted by cattle at all stages of growth. The feeding of perennial peanut increases milk production in dairy cows, and it improves stocking and calving rates. With regard to beef production, "steer gains average 1.7 lbs./head/day grazing perennial peanut as compared to 1.0 lbs./head/ day on bahiagrass (Perennial Peanut Uses). This represents an increase in growth of 70%. As previously noted, feeding high-quality forage such as the perennial peanut helps in reducing the production of enteric methane.

Fermenting the perennial peanut creates bypass protein. "Initially, on day zero of fermentation, the material presented a third of soluble protein, one third as bypass protein and the remaining as unavailable protein, whereas by effect of the fermentative process the content of soluble protein remained similar (33.05 %), the bypass protein increased to 51.38 % and unavailable protein reduced to 16.04 %. Perennial peanut silage can be used as feed for animals of high productive potential (milk and meat) starting ten days post-fermentation, since the system becomes stabilized and it presents a great proportion of bypass protein"(CIAT 17434).

Some large dairy companies in Vietnam have begun importing alfalfa from the US. Not only does this hurt the Vietnamese balance of trade and rob many small farmers of a potential livelihood, but it is also catastrophic for states such as California that export huge quantities of alfalfa. Alfalfa is grown on over 400,000 hectares in California, and this one crop "sucks up more water than any other crop in the state. And it has one primary destination: cattle" (Meat Makes the Planet Thirsty). While California is suffering one of its worst droughts on record, the alfalfa it produces sucks up almost 400 million cubic meters (100 billion gallons) of water each year. "Ridiculously unsustainable" is the only way to describe the export of alfalfa to Vietnam and other Asian countries (Watering California's Farms).

Attempts to grow alfalfa in highlands areas of Vietnam have failed due to low yields. But even if yields could be increased, land would have to be set aside specifically for this purpose. This is not the case with the perennial peanut, as previously explained. It can be grown successfully under shaded conditions in existing coffee plantations and orchards of all kinds. It can be grown in hilly highland pine forests and within bamboo groves.

The import of alfalfa is not the only thing that hurts Vietnamese dairy farmers. Milk can be easily transformed into powder and traded as a global commodity. But the price of powdered milk is artificially low for two reasons: it is "based on heavily subsidized surplus production in Europe and the U.S." as well as "a low-cost model of export production in New Zealand and Australia" (The Great Milk Robbery). "By 2006, the Cato Institute pegged the overall value of federal [US] dairy subsidies—tax dollars that the government doles out to farmers to supplement their income and ensure a robust commodities market—at $4.5 billion. By another measure, that's a quarter of the wholesale price of every gallon of milk sold, or 40 percent of dairy farmers' incomes" (Cowed).

In Vietnam, powdered milk makes up 80% of the national market, and large Vietnamese milk processors set their local procurement prices for fresh milk according to international powdered milk prices. The Vietnamese farmer receives no government subsidies, as in the US and Europe. Therefore he's in no position to compete. The prices that he receives are often at or below his cost of production. The global trade in milk powder has a devastating effect on the economics of milk production in Vietnam.

In the US and other countries, commodity crops such as wheat, corn and soya are also subsidized (Industrial Crop Production). "In recent years, farm subsidies [in the US] have remained high even in years of near-record profits" (Farm Subsidies over Time). All of this greatly undermines Vietnam's sovereignty in food production.

RECYCLING BONE

Phosphorous is a finite resource. As much as 70% of all high-quality phosphorous lies in the hands of one country: Morocco. In a few decades from now, this hold on phosphorous could be "the most important quasi-monopoly in the history of man" (Welcome to Dystopia! Entering a long-term and politically dangerous food crisis). Apatite reserves are dwindling, and they are becoming increasingly contaminated with pollutants such as cadmium and uranium. In as little as 25 years, many of these reserves will no longer be economically exploitable. Some predict that massive world-wide starvation will follow in the decades to follow. Also, "the chemical production of P fertilizers based on the use of high-grade (>32–35% P content) rock phosphate is an inefficient, high-energy process that generates residual materials harmful to the environment" (Biochar of animal origin: a sustainable solution to the global problem of high-grade rock phosphate scarcity? And Making Green Organic fertilizer from Bones). So it's imperative that we seek out ways to recycle sustainable sources of phosphorous wherever they can be found, as suggested in these two papers.

In Vietnam cow and pig bones are boiled anywhere from three to six hours to make stock for noodle soups such as Pho, Bun Bo, Hu Tieu and Banh Canh. Such intensive boiling demands a great deal of energy - energy usually derived from bottled gas, coal, charcoal or wood. However if the gasifiers discussed previously in this paper are used to boil bone, most of this huge energy cost can be avoided. After bone is boiled, it's usually thrown away and ends up in landfills. The discarding of spent bone is incredibly wasteful, since about 80% of the phosphorous within an animal is found in bone.

So instead of dumping spent bone in landfills, we suggest that it be gasified along with biomass pellets. Or bone could be crushed into a fine powder, dried, pelleted along with biomass, and then gasified. As fresh bone is being boiled in a pot above the gasifier, spent bone can be charred at the same time within the reactor of the same gasifier. This results in the simultaneous production of broth, bone char and biochar. Heat is not wasted as in typical bone char kilns.

Bone char is a porous, granular material that consists of about 80% tricalcium phosphate. Bone char is used in water filtration to remove radioactive isotopes, fluoride, bromine, chlorine and metal ions. It is highly effective (more so than activated carbon) in adsorbing metals such as copper, zinc, cadmium, arsenic and lead. It is also used in sugar refining as a decolorizing and de-ashing agent.

In contrast to rock phosphates which might contain uranium, cadmium, lead, copper, arsenic and other heavy metals, bone char is free of such contaminants. Therefore, bone char can be crushed and safely incorporated into the soil. It is referred to as a "soft" phosphate in that it is not as soluble and leachable as commercial phosphate. P-solubilizing bacteria (such as strains from the genera *Pseudomonas*, *Bacillus* and *Rhizobium*), actinomycetes, fungi (such as *Aspergillus* and *Penicilium*) and AM fungi can convert tricalcium phosphate into plant-available forms of P (Phosphate solubilizing bacteria from subtropical soil and their tricalcium phosphate solubilizing abilities and Improvement in bioavailability of tricalcium phosphate to Cymbopogon martinii var. motia by rhizobacteria, AMF and Azospirillum inoculation and Enumeration and detection of phosphate solubilizing bacteria from the gut of earthworm varieties). In this last study, we see that the gut of the earthworm and worm castings usually contain high concentrations of P-solubilizing microbes.

In 2009 Warren at al. determined that animal bone char is a P fertilizer of solubility intermediate between phosphate rock and triple superphosphate (Dissolution of phosphorus from animal bone char in 12 soils and BIOTECHNOLOGICAL APPROACHES TO IMPROVE PLANT P NUTRITION BASED ON WASTE NATURAL PRODUCTS). In soils rich in P-solubilizing microbes and AM fungi, the effectiveness of bone char is reported to be as good as superphosphate fertilizer.

Acetic or lactic acid can be added to bone char to produce phosphoric acid. Phosphoric acid should not be applied to the soil. But it can be applied to certain plants (such as coffee) as a foliar fertilizer spray. Phosphoric acid is also used in the chemical activation of activated carbon (Agricultural Waste Conversion to Activated Carbon by Chemical Activation with Phosphoric Acid).

In this paper we suggest that biochar be used as an ingredient in the lactic acid fermentation of biomass. If the biochar used in fermentation contains bone char, lactic acid solubilizes tricalcium phosphate. If the fermentation medium is deficient in phosphorous, the co-fermentation of bone char supplies deficient phosphorous and enhances lactic acid production. This in turn enhances the nutrient value of the fermented biomass being fed to pigs, chickens and cows.

ENERGY TECHNOLOGIES AT THE HOUSEHOLD LEVEL

In this paper we have spoken of the great things that small gasifiers can do at the level of a household or small farm. They can provide high-grade heat for boiling, cooking, drying, roasting, distillation and charring bone (see diagram). But should the role of gasifiers be expanded over and beyond the production of high-grade heat? As we stated at the beginning of this paper, our greatest temptation is to focus on a single solution that overrides all else. As great as gasifiers might be, we propose a mix of technologies at the household level:

1. For the generation of electricity: solar panels.
2. For the generation of low-grade heat: solar hot-watering heaters (heat tubes).

3. For the generation of high-grade heat: top-lit updraft gasifiers.

The cost of solar panels is more than 100 times lower than in 1977 (Cost of Solar Panels). "What is really important is that the cost of electricity from solar panels is now lower than the cost of retail electricity for most people." In the last three years, the cost of solar has dropped by about 60%; "from around $1.31 a watt to around $0.50 in 2014" (Why solar costs will fall another 40% in just two years). Some predict a drop down to $0.40 per watt by the end of 2016. In the long term, Deutsche Bank sees a drop down to about $0.20 per watt.

Since solar technology has become so cheap, we propose that households in Vietnam be equipped with enough solar panels to meet all of their electrical needs. When solar panels are mounted on existing roof-tops, no land has to be set aside for power generation. Households should also be in a position to sell electricity back to the grid. To the extent that the flow of electricity from household to grid takes place, less electricity has to be generated from fossils fuels or from hydroelectric dams. Installing hydroelectric power plants in the lower Mekong is a particularly bad idea.

In the Mekong region about 48 million people "depend directly on the river for food and livelihoods" (Mekong dam spree could create regional food crisis). Eleven hydroelectric dams have been proposed for this region, and this could have disastrous consequences:

Economically, the 11 planned dams could cost the Mekong countries—Thailand, Vietnam, Laos, and Cambodia—nearly half a billion US dollars annually in lost fish catch. Replacing the lost fish protein with protein from livestock—such as cattle, pigs and poultry—would also require an additional 4,863 square kilometers (3,021 square miles) of land, according to the study. Water requirements would also need to be boosted to irrigate crops for the livestock. For example, the 11 dams would require Cambodia to consume 29-64 percent more water for its agriculture, and Laos would need 12-24 percent more. An additional 77 dams are planned for the river by 2030.

Hydroelectric dams could potentially disrupt food production throughout the Mekong region (also see 'A Threat to Cambodia's Sacred Forests' and Large Dams Just Aren't Worth the Cost and No More Dams on the Mekong and COP21 – Mekong Dolphin Extinction, Hydropower & Climate Change). The building of dams contributes to the release of arsenic (Dams may worsen arsenic problem: study). The building of dams raises "the global human consumption of freshwater to a much higher level than previously thought" (Global Freshwater Loss).

Solar power offers great hope in averting such problems. But a solar PV system has its limitations. It should not be used to generate high-grade heat. If used in this way, the investment in solar technology would be too great. For example, an investment of over $500 US in solar panels would be needed to supply electricity to a one kW electric stove costing $27 US. Even though generating high-grade heat by means of electric stoves is a bad idea, unfortunately there is a growing trend among the more affluent in urban areas of Vietnam to move in this direction.

Many in Vietnam see bottled gas as dangerous and expensive. Thirty to forty per cent of bottled gas in Vietnam is distributed by unauthorized dealers. They distribute gas bottles that are not properly tested and certified, and from time to time, these bottles explode (Gas cheats put explosion fears into every home). The fear of gas in combination with its high price leads households to turn to induction and infrared stoves for cooking (Induction stoves popular as gas prices rise).

To meet this growing demand for electricity, some advocate using gasifiers to generate electricity. But in order to route syngas to an internal combustion engine coupled to a gen-set, syngas must be cooled and filtered. On the one hand, if syngas is produced at high temperatures, it exits the reactor at temperatures greater than 500 ^{0}C. Cooling down this gas involves a huge inefficiency. On the other hand, if syngas is produced at lower temperatures, tars and oils are produced, and they have to be condensed out of the stream of syngas – again another inefficiency. Furthermore, the filtration of particulate matter from syngas is not a simple procedure. If filters should fail even for a few minutes, the internal combustion engine gets damaged. Then finally there is the inefficiency associated with making electricity from even the coolest and cleanest of fuels.

Since the gasification of low-grade biomass to make electricity at the household level is inefficient, impractical and expensive, there are those who advocate operating gasifiers for power generation at the village level. But even in communist Vietnam, what happens at the village level will inevitably be taken over by private enterprise (requiring suitably trained engineers and mechanics) whose main goal is to make money and maximize profits by selling electricity to the poor. The poor should not be dependent on village gasification to meet their need for electricity. The generation of electricity for household use should be as decentralized as possible, with each household fully equipped to produce all of the electricity it needs. If households are equipped with sufficient solar technology, large gasifiers making electricity at the village level are not needed.

If big companies start buying up biomass to fuel large gasifiers to make electricity at the village level, this will inevitably drive up the price of biomass. In many places in Vietnam, rice hulls and rice straw are relatively inexpensive, and things should stay this way for as long as possible. Traders in Vietnam have already started pelletizing rice hulls and exporting them to countries such as India. India is now buying rice hull pellets made in Vietnam, even though India has a lot of rice hulls and other low-grade biomass of its own that it uselessly discards or burns. The export of rice hull pellets to India has already started to drive up the price of rice hulls in certain areas of the Mekong. This is a good example of the total nonsense that so often characterizes global trade.

Furthermore, large rice and coffee exporting companies typically burn coal to generate the high-grade heat needed to dry paddy rice and coffee beans. Coal is barged and trucked in over long distances from the north of Vietnam. Buy why use coal? A top-lit updraft gasifier of a 500 mm diameter using pelleted biomass can generate up to 60 kW of high-grade heat (see drawing, video and jpegs 001, 002, 003, 004, 005, 006, 007 and 008). Such a gasifier costs less than $150 US ($2.50 US per kW), and the burn time on pellets with a net reactor height of 75 cm is about 5 hours. Any number to these gasifiers can be operated to provide high-grade heat for the drying of paddy rice and coffee beans on any scale. A larger 800 gasifier (165 kW unit) has also been designed (see drawing 001 and jpegs 001, 002, 003, 004, 005, 006, 007, 008 and 009). This gasifier should cost less than $375 US, and the burn time on pellets is also about 5 hours.

In Cambodia electricity has always been relatively expensive. So companies were quick to seize the opportunity and started making electricity from rice hulls using gasifiers. At the same time, many poor people in Cambodia burn low-grade biomass in smoke-filled kitchens to cook meals and warm water. Some chop down trees to make charcoal – a charcoal made in dirty kilns that emit a lot of black carbon. This is one among many factors that have contributed to serious deforestation in Cambodia (Deforestation in Cambodia). "Cambodia has one of the highest rates of deforestation in the world, third to only Nigeria and Vietnam." As a result of the installation of gasifiers making electricity from biomass, rice hulls in Cambodia are expensive, and the price of electricity still remains unaffordable for the poor (Electricity Tariffs in Cambodia).

Many poor families in the Mekong spend almost $10 US per month on ice. At the household level, a small adsorption refrigeration unit could be used to make ice. The adsorption refrigeration unit that we are designing is powered entirely by gasifier heat. It has no moving parts. It requires no electricity. It can pay for itself in three to six months. While making ice, it also makes warm water and does away with the need for expensive solar hot water heaters. Larger commercial adsorption refrigeration units, likewise powered by gasifier heat, could be used to ice fish or other perishable foods. The production of ice in tropical Vietnam demands a lot of electricity, and eliminating most of the cost of electricity in this regard is essential.

In our experience, most poor families in rural areas of Vietnam who buy top-lit, updraft gasifiers use them about four times or five times each day. A single household can consume as much as four kg of biomass per day. As more households buy gasifiers, the demand for biomass will increase. As households turn to adsorption refrigeration units to make ice and warm water, the demand for biomass will increase. As farmers discover more uses for gasifiers in areas such as drying, boiling, roasting and distillation, the demand for biomass will increase. As farmers learn to raise pigs, chickens and cows on bedding, the demand for biomass will increase. Finally as people in urban areas switch from bottled gas to small gasifiers fueled by biomass pellets, the demand for biomass will increase.

A small pellet gasifier of a 100 mm diameter is all that is needed for cooking a meal in a household setting. It puts out over 3.5 kW of heat. It costs less than $25 US (about 90 times cheaper than solar per watt). It is made out of high-quality, long-lasting stainless steel (BA304). It has a burn time of about an hour and 15 minutes. It produces biochar pellets that have a greater value than the raw pellets from which they are derived. It does away with the need for unsafe bottled gas. It replaces induction or infrared stoves, and best of all, it consumes less than 200 milliwatts of electricity. Here a tiny input of one unit of electricity gives an output of 15,000 units of high-grade heat. Solar supports small-scale gasification in a marvelous way.

By the way, households in the developed world should also cook meals using syngas. They should not burn fossil fuels and then try to make restitution for such behavior by means of carbon credits. Passing on the burden of doing things correctly to poor people in developing countries is a cop-out. It's immoral. In a single day, a household can produce between one and two kilograms of biochar. If households everywhere were to use syngas to cook meals, a lot of biochar would be produced. Dedicated biochar kilns, where all of the heat is wasted, would not be needed.

Just as electricity from solar panels should not be used to power electric stoves, gasifiers consuming low-grade biomass should not be used to make electricity. Biomass is far too precious to be wasted in the inefficient generation of electricity, especially at a time when solar panels are so cheap and when the demand for high-grade heat is potentially unlimited.

Vietnam should wake up to the enormous potential that solar has to offer in generating electricity. If Vietnam needs examples of what solar panels can do, it should turn to two countries that have taken solar quite seriously in meeting the electrical needs of the poor: Peru and Thailand.

The Peruvian government is providing its poorest two million people with electricity by giving them solar panels for free (Peru To Provide Free Solar Power To 2 Million Of Its Poorest Residents). By the end of 2016, Peru hopes to equip 95% of its people with solar panels. The entire program in a country with a population of almost 31 million people will cost $200 million US.

The Thai government will pay owners of solar panels a feed-in tariff of over $0.20 US per kWh. If villages pool their resources in installing and owning large ground-mounted arrays, they will get over $0.30 US per kWh (Thailand Adding 1,000 MW of Solar with New Feed-in Tariffs).

Vietnam might seek international aid in giving solar panels to all poor households for free. It might incentivize the more affluent by offering feed-in tariffs at reasonable rates. Vietnam would then be in a position to drop plans to build hydroelectric power stations in the Mekong. Vietnam should start transitioning to a low carbon economy where entire villages within the next few years are totally off-grid (The State of Germany's Move to "Energiewende" and Green World Rising). Solar panels in the hands of the poor can change the world, as Bunker Roy explains in Learning from a Barefoot Movement. Also see Electrifying India, with the Sun and Small Loans.

A plant can absorb only so much energy from the sun, after which point any further increase in the amount of sunlight it receives does not result in an increase in the rate of photosynthesis (Photosynthesis Investigation Guide). Back in 2004, Akira Nagashima discovered that it's possible to combine PV systems with farming systems (Japan Next-Generation Farmers Cultivate Crops and Solar Energy). By carefully positioning and spacing solar panels above crops, he figured out that solar panels can occupy about 32% of farmland space without interfering with plant growth. Some farmers in Japan are now able to earn 15 times more money from the sale of electricity than from sale of vegetables. With a lot more money to be made in the countryside, the hope is that more young people in Japan would become farmers.

To fulfill its entire demand for electricity through farmland power generation, Japan would need about 7 million acres of farmland. No problem here at all. Japan currently has over 11.3 million acres of farmland that could be made available for the production of electricity. Japan does not need nuclear power to fulfill its need for electricity. In a country plagued with earthquakes and tsunamis, nuclear power stations are far too dangerous. Also Japan's current fascination with methane hydrate carries a lot of risk (Japanese companies band together to test methane hydrates). Drilling in sediment for methane hydrate could destabilize the seabed and cause massive tsunamis. It could also cause catastrophic releases of methane into the atmosphere (The Risky Business of Mining Methane Hydrate).

This farmland power generation concept could be more easily applied in Vietnam than in Japan. In Vietnam, a lot of farming is still done manually without the use of large tractors and harvesters. Large equipment calls for high levels of clearance and therefore more expensive structures to support solar panels. Vast areas of existing farmland could fulfill most of Vietnam's electrical needs. If there is any shortfall, wind turbines could be employed.

In windy coastal and highland areas, Vietnam should turn to wind turbines to meet its need for electricity (Wind power industry in Vietnam: First wind powered turbine factory). "Surveys show that around 28,000 square kilometres of Vietnam's land has an average wind speed of over seven metres per second at the height of 65 metres above sea level. This speed is considered suitable by international experts, who offered an assessment potential of over 110,000 megawatts (MW)." Vietnam might draw inspiration from Denmark, a country that derived 42% of its electricity from wind in 2015 (Denmark Just Set Yet Another World Record for Wind Power).

An impressive group of scientists believe that it is possible to extract $C0_2$ from ambient air to make a variety of liquid fuels "at a cost competitive with fossil-based fuels" (Closing the Carbon Cycle: Liquid Fuels from Air, Water and Sunshine). They cite a figure as low as $1.60 US per gallon of gasoline. The system they propose would "operate entirely on carbon recycled from the air, locally-available water, and sunlight."

The authors propose the use of an anionic exchange resin to capture CO_2 from ambient air. The anionic exchange resin that they propose has a surface area of 4 m_2/kg. Biochar produced at 600 C or higher typically has a surface area of about 40 hectares/kg. This is 100,000 times more surface area than the proposed anionic exchange resin (see Carbon dioxide capture using biochar produced from sugarcane bagasse and hickory wood). Also, biochar is much cheaper than activated carbon, also being proposed for CO_2 capture.

Scientists at Stanford and Penn State are developing a similar approach. But here they use microbes: Stanford Scientists Use Microbes to Make 'Clean' Methane. Instead of methanogens, other scientists at the University of Massachusetts propose to use acetogens: Powering microbes with electricity: direct electron transfer from electrodes to microbes).

If the production of liquid fuels is done correctly, we have liquid fuels without using fossil fuels or biomass. The demand for liquid fuels is so great that if they were generated from biomass, there would not be enough biomass available for transformations at Levels 1 through 4. Waste biomass is needed in the production of feed and fertilizer, and without feed and fertilizer, we have no food. The production of food must be granted a higher priority than the production of fuel.

We need radical change both in agriculture and in the production of liquid fuels. The production of liquid fuels as propose above takes CO_2 out of the air. But since liquids fuels eventually get burned, this approach is carbon neutral. Agriculture, by employing all four levels of waste transformation, makes use of nutrients in a highly efficient manner and ultimately puts carbon in the soil in many different ways. This approach is carbon negative. It is imperative that we combine both approaches to effectively combat climate change.

DO WE NEED PASTURELAND?

There are about one billion pigs, 19 billion chickens and about 1.4 billion cows on our planet (henceforth all referred to as animals). Imagine if we could collect most of their waste, along with the waste of other domesticated animals, and transform it into a high quality feed (larvae and worms) and fertilizer (vermicompost and compost).

But to transform their waste at the highest possible level, fecal matter must be collected fresh, and the nutrients in urine must be rapidly sorbed or immobilized. The key to accomplishing both of these tasks lies in housing animals indoors on bedding enriched with biochar. If we let these creatures roam outdoors, only pastureland gets fertilized, and this fertilization can be highly inefficient due to losses of P in runoff as well as losses of N in forms of ammonia, nitrous oxide, nitrogen oxide and nitrate. "Urine of grazing livestock is the greatest contributor to leached nitrogen (N) in our environment" (Why we need to know what and where cows are urinating).

When a cow is raised outdoors, heavy losses of ammonia can occur during urination and after urine patches form (Nutrient Losses in Pasture). Heavy rainfall can cause losses of nutrients by leaching and runoff. Fertilization can occur at the wrong time of the year, even at the wrong time of the day. The cow might eat uniformly, but when she excretes, this is anything but a uniform event. Grasses receiving excreta get grossly over-fertilized and can easily get scorched or killed. At the same time, large areas of pastureland can go without fertilization for several years. Rotational grazing helps only to a limited extent in the spatial and temporal distribution of excreta. Also, let's not forget that soil nutrients that give rise to meat, bone and milk are continuously removed from pastureland and are seldom replaced, except perhaps, through the problematic input of sewage sludge or chemical fertilizers.

On the merits of Allan Savory' Holistic Method and other aspects of rotational grazing, please see: Why Allan Savory's TED talk about how cattle can reverse global warming is dead wrong and Allan Savory tells us that increasing livestock can reduce desertification and reverse climate change – but where is the scientific evidence? and All Sizzle and No Steak and Cows Against Climate Change: The Dodgy Science Behind the TED Talk and An Evidence-Based Assessment of Prescribed Grazing Practices and TED Talk Teaches Us to Disparage the Desert and Alan Savory gives a popular and very misleading TED talk and Asa Feinstein – To Combat Desertification: Just Add Cows? and Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China and Grazing Cattle: The New 'Invasive Species' and Eat more meat and save the world: the latest implausible farming miracle and Commentary: A critical assessment of the policy endorsement for holistic management and Livestock and climate: Why Allan Savory is not a savior and Comments on Allan Savory's Proposed Application of "Holistic Management" to Grasslands, Including Desert Grasslands, for the Purpose of Increasing Sequestration of Atmospheric Carbon and Holistic Management: Misinformation on the Science of Grazed Ecosystems and Campaign to buy ranchers' grazing permits is the way to save public range and Allan Savory is not Galileo and Meat, Lies, & Videotape (A Deeply Flawed TED Talk) and The Ecological Wisdom of Leaving Nature Alone and Allan Savory's proposed application of "Holistic Management" and The Cowboy and the Desertification of the West and Allan Savory: Myth and Reality and Allan Savory: Holistic Management in Grassland Management and The Savory Method Cannot Green Deserts or Reverse Climate Change and Biological Soil Crusts: Ecology and Management.

In general, animals cannot be allowed to roam freely outdoors depositing waste on farmland. Vegetable gardens get demolished. One beautiful exception is the raising of ducks in rice fields as explained in Ducks in Rice Paddies under Spotlights. Animals, of course, can be raised outdoors on pastureland. But unfortunately there is no way to collect waste deposited outdoors and return it to farmland. In other words, farmland, especially in a co-cropping context, can supply feed for animals, but animals raised outdoors on pastureland, in general, cannot supply fertilizer for farmland. When animals are raised outdoors, loops are not closed, and very little cascades back to farmland.

By 2015 the world demand for chemical fertilizers is projected to reach about 190 million tons (Current world fertilizer trends and outlook to 2015). If we were to stop using chemical fertilizers as strongly recommended in this paper, we would be obliged to find organic (non-chemical) forms of fertilizer in large quantities. Those who argue that it would be impossible to produce enough organic fertilizers to replace chemical fertilizers are absolutely right, so long as the potential of domestic animal waste is not fully exploited. We have to stop looking at domesticated animals merely as sources of food. We must learn to look at them as vital and indispensable sources of fertilizer.

Mao Zedong once said that a pig is a "fertilizer factory on legs." But in its reckless rush to provide cheap meat to its citizens, China pays no attention to what Chairman Mao said. "The billions of tons of waste China's livestock produce each year are one of the biggest sources of water and soil pollution in the country, according to the Ministry of Agriculture." China desperately needs to learn how to transform these billions of tons of livestock waste and return it to farmland. Vietnam follows closely behind China in its inability to manage livestock waste and return it to agriculture.

It takes a fair number of animals to support one hectare of farmland. For example, it is estimated that in Vietnam it would take about five cows or fifteen pigs to fertilize one hectare of coffee co-cropped with banana and perennial peanut. If all of Vietnam's 550,000 hectares of coffee were fertilized with transformed cattle waste, about 2.75 million of Vietnam's 8.40 million beef cattle (about 33%) would be needed for this one crop alone. Likewise, if all of Vietnam's coffee fields were fertilized with transformed pig waste, about 8.25 million of Vietnam's 26.30 million pigs (about 31%) would be needed. Such a large number of supporting animals per hectare of farmland makes the raising of animals independently of the cultivation of plants unnecessary.

When growing crops is fully integrated with raising animals, vast areas of existing farmland start fulfilling all of the functions of pastureland. The fact that Vietnam has so little pastureland should not be a problem in fulfilling its appetite for beef and dairy products. The integration of growing crops and raising animal gives rise to levels of productivity unheard of in conventional farming systems. Only when co-cropping and co-raising become deeply intertwined does agriculture become sustainable. Along with this co-cropping and co-raising, we should not forget the co-generation of electricity on farmland as explained previously. A lot can be crammed quite intensively and productively into a single hectare of farmland. When animals are housed indoors, the roofs of barns can also provide space for solar power generation.

So long as human food (such as corn and soya) is not used to feed animals, the demand for animal source food in developing and emerging economies should not be viewed as a threat. The fact that people eat meat (a concentrated form of plant nutrients) is not the problem. The problem lies in the unsustainable and wasteful manner in which meat is conventionally produced. For example, in the United States, it is not uncommon to see more than an hectare of pastureland devoted to raising a single cow, while right across a fence lies a corn field fertilized completely with chemical fertilizers. Even pastureland gets fertilized with chemical fertilizers (Fertilize Pastures November - February).

Here there's a total disconnect between the raising of plants and the raising of animals. The scale of this disconnect only comes into perspective when we realize that "livestock now use 30 per cent of the earth's entire land surface, mostly permanent pasture but also including 33 per cent of the global arable land used to producing feed for livestock" (Rearing cattle produces more greenhouse gases than driving cars, UN report warns). See as well the The Alarming Environmental Costs of Beef and The Hidden Cost of Hamburgers. Most of the 38.45 million hectares of corn and most of the 30.35 million hectares of soya in the United States goes to feed livestock. Just about all of this animal feed production involves mono-cropping, and corn involves the heavy use of nitrogen fertilizers (think back on the Dead Zone in the Gulf of Mexico). The story gets worse.

Creating space for pastureland is a major driver behind deforestation. "Some 70 per cent of former forests in the Amazon have been turned over to grazing." Magnificent rainforests were destroyed to provide pastureland for cattle in order to satisfy the US appetite for cheap burger meat (Is Meat Sustainable?). Native grasslands were once the largest ecosystem in North America. They were destroyed and replanted with monoculture grass for the large-scale grazing of cattle. When bison and pronghorn were replaced with domesticated animals, enormous devastation followed. According to Richard Manning, "no other system suffered such a massive loss of life."

"At the same time herds cause wide-scale land degradation, with about 20 per cent of pastures considered degraded through overgrazing, compaction and erosion. This figure is even higher in the drylands where inappropriate policies and inadequate livestock management contribute to advancing desertification." We must do all that we can to reduce and eventually eliminate the need for pastureland.

The first step in restoring degraded pastureland lies in putting domesticated animals indoors. When this happens, vegetation begins to cover barren eroded soil, and the soil eventually becomes rich in carbon. Rainwater infiltrates the soil. Springs and streams often appear in areas that were once deserts. The soil comes alive and functions again as soil. The soil becomes the key element in a functional ecosystem. The soil possesses far more value than anything derived from it. Free of course of grazing animals, farmland bears fruit, vegetable and grain in abundance. Chemical fertilizers are not needed. Organic matter from plants and animals is all that is needed to fertilize the soil.

When the hydrological function of the soil is restored, that is, when water is retained within soil pores and organic matter, well above the water table, irrigation using groundwater is seldom required. This so called "green" water not only transports nutrients between mutualistic soil networks, but it also carries information between them via hormones and growth factors. When water is retained within soil pores and organic matter well above the water table, water tables are not depleted, aquifers are not salinized, land does not subside, and arsenic poisoning is not an issue (Arsenic contamination of groundwater). Imagine the harm done to mutualistic soil networks when soil is irrigated with groundwater containing arsenic. Watering cattle with arsenic contaminated groundwater has a hazardous effect on the health of these animals, and arsenic contaminates meat and milk. In the section on intensive agriculture, we will revisit the problem of arsenic in groundwater.

When beef and dairy cows are raised indoors, it becomes much easier to control what they eat and drink. As we have seen previously, fermenting high-quality leguminous forage along with biochar and neem cake helps in reducing the production of enteric methane. By contrast, letting cows graze outdoors on low-quality grasses leads to high emissions of enteric methane. Also, controlling water quality by not letting cows drink from ponds or lakes can increase growth and reduce enteric methane emissions. Water quality from ponds or lakes can be compromised by salinity, acidity, algal growth and a variety of toxic chemicals from fertilizers, herbicides and pesticides (Water requirement for sheep and cattle). High levels of iron, magnesium, arsenic, lead, mercury, selenium and fluorides can be found at times in pond and lake water. If animals are raised indoors, it's so much easier to safeguard the quality and availability of their feed and water.

Even with the tightest and strictest control on what beef and dairy cows eat and drink, it will be impossible to reduce enteric methane emissions down to zero. Perhaps the best result one might hope for is a 60% reduction in enteric methane. But if cows are raised indoors, it should be possible to oxidize a good portion of the methane they produce by means of methane-eating bacteria residing on the large surface area that biochar provides. Research with biochar in oxidizing methane from landfills is well underway (Enhanced Microbial Methane Oxidation in Landfill Cover Soil Amended with Biochar and Effects of Biochar-Amendment to Landfill Cover Soil on Microbial Methane Oxidation: Initial Results). A very high tax should be placed on any enteric methane that escapes into the atmosphere.

In countries where rabbit meat is prized, one might consider raising rabbits instead of cows. The rabbit has a tubiform haustrated stomach that effects the removal of hydrogen by acetogenesis rather than methanogenesis. Acetate is absorbed by the rabbit and contributes to its growth. Per kg of forage eaten, the rabbit produces about one tenth the methane that a cow produces. See Development of an Emissions Model to Estimate Methane from Enteric Fermentation in Cattle as well as Methane Output of Rabbits and Guinea Pigs. In Perennial Peanut: Developments in Animal Research, we see that the feed conversion ratio of rabbits fed perennial peanut is an impressive 2.6. It is easy to collect fresh rabbit excreta and feed it to BSF larvae.

If cattle graze outdoors, fences are needed. But unfortunately fences can limit the daily movement and seasonal migration of wildlife. As wildlife (including birds) often collide with or get entangled in fences, they get injured and die in large numbers. Utah State University completed a study on 600 miles of fence and noted that "On average, one ungulate per year was found tangled for every 2.5 miles of fence" and "on average, one ungulate was found dead next to, but not in fences, every 1.2 miles of fence"(Fencing with Wildlife in Mind). One might build special fences designed to minimize wildlife injury and death. But this is never an adequate solution to the problem.

Fences are expensive: "Fencing costs are one of the most expensive aspects of livestock grazing" (Estimated Costs for Livestock Fencing). Repairing older fences can be a constant chore. Strainer posts can move, lift or rotate. Staples can rust. Fence wire, especially foot wire, can rust. Battens might have to be straightened, tightened or replaced. Often entire sections of fence have to be rebuilt or replaced. In spite of all this effort, domesticated animals still break out and escape. Chasing after domesticated animals that have broken out is time-consuming and costly. Some get lost and are never recovered.

But if domesticated animals are housed indoors in sturdy barns, fences are not needed. All of the money devoted to constructing and repairing fences, and to chasing after livestock that have escaped, should be devoted to building barns to house livestock indoors. But the best benefit of all in doing away with fences: wildlife are not injured or killed.

When cattle are raised outdoors, horseflies and deer flies can be a serious menace to their comfort and health: "Horse flies and deer flies are significant livestock pests with their painful and persistent biting behavior. Heavy attacks can lead to reductions in weight gains of beef cattle, reduced milk yield, reduced feed utilization efficiencies and hide damage from the puncture wounds… The adult flies serve as vectors for many disease agents (viruses, bacteria, protozoans and nematodes) of animals" (Horse Fly/Deer Fly). The best option by far in the control of horse flies and deer flies is to house cows indoors with appropriate fly screens in place.

When cattle graze outdoors, they can become infested with ticks (Ticks of Domestic Animals). "Ticks are serious vectors of human and animal disease agents; transmitting a greater variety of infectious organisms than any other blood-sucking arthropods. Ticks are known to transmit numerous protozoan, viral, bacterial and fungal pathogens" (Ticks). Ticks can damage cattle hides and render them worthless. They can reduce milk production and live animal weight. They can cause suffering, pain, extreme annoyance, anorexia, anemia, paralysis and death. "Heavy infestations can kill calves and even adult cattle" (Cattle Ticks).

If cattle are raised indoors, the farmer has much better control over the problem of tick infestation. Neem oil is especially useful in this regard: "Neem oil, herbal oil extracted from the seeds or leaves of neem tree will serve as a valuable tick opposing product on its application over the animals" (Tips and Advice on Making Neem Oil Tick Repellent). Neem oil also repels biting flies and mosquitoes.

When cattle are raised outdoors, they are often faced with climatic extremes involving heat, cold, wind, rain, snow, ice or blizzard (Cattle Guidelines for the provision of shelter). We noted a similar problem with regard to raising pigs outdoors. As climate change brings with it greater extremes in weather events, the rancher or dairyman should reexamine the "wisdom" of letting cattle graze outdoors.

Most pastureland provides cattle insufficient access to shade. Direct sun in summer can lead to heat stress and exhaustion, especially in the case of calves and pregnant cattle. Calves subjected to heat stress often experience higher rates of mortality. When it is too hot, cattle drink more, eat less and spend less time chewing their cuds. Feed intake and feed efficiency are reduced. Daily weight gain and milk productivity fall. Percentages of milk fat and protein drop, and there are lower rates of conception. A study on bison predicts that domestic cattle "will drastically reduce in weight as the climate warms" (Cattle Weight Loss Means Slimmer Profits).

Bad things happen as well in cold weather. New-born calves, calving cows as well as sick or injured animals are particularly vulnerable in cold weather. In cold weather, weight gain, milk yield and milk quality can sharply decline. "Studies suggest that a yearling's energy requirement may increase 2.5 fold during an extreme winter event." Cattle housed indoors on soft, warm bedding fare much better during cold winters than cattle that roam outdoors.

Some have romantic notions about how nice it is when cattle are allowed to roam freely outdoors. But the cow is a highly domesticated animal. It has no aversion to being housed indoors as long as its basic needs are met. In this study (Cows Show Preference to Indoor Housing), high yielding dairy cows were given a choice to stay indoors or roam freely outdoors in pasture. "When given a choice, the cows spent 91.9% of their time indoors, and time spent indoors was influenced by environmental conditions."

Minimizing the impact of extreme weather events by bringing cattle indoors can significantly increase productivity. It can prevent a lot of suffering and possibly even death. When cattle are housed indoors, the farmer is in a much position to watch over them and to make sure that all of their nutritional, physiological and health needs are being met. He is also in a much better position to breed stock correctly, minimize competition and injury during breeding, and prevent inbreeding. Since the farmer can exercise much better control over breeding, he is far less likely to slaughter pregnant cows and heifers (A review on cattle foetal wastage during slaughter and its impacts to the future cattle herds in Tanzania). And he can better predict the timing of births so as to be present in case there are problems in calving. When calving takes place indoors on bedding, it does so under ideal and safe conditions.

There's another big advantage associated with raising animals indoors. When domesticated animals are housed indoors, clear lines can be drawn between domesticated and wild.

Domesticated animals are bred to produce food for humans, and they are ill-equipped to fend for themselves against wild carnivores. But if domesticated animals are housed indoors, wild carnivores cannot prey upon them.

We see increasing numbers of wolves in the United States (As wolves return, so do tensions with ranchers), as well as in Russia, Spain, Greece, Germany, Holland, Belgium, Denmark, Slovakia, Poland, Alpine Italy, Croatia, Romania, the Apennines and Alpine France (From the steppe to central Spain, Europe echoes to the howl of the wolf). But the killing of the American gray wolf still takes place (High Noon for the Gray Wolf). "Some say wolves are a threat to their livestock investments (despite the existence of generous rancher-compensation programs in all wolf states save Alaska)." Sadly there are only 5,000 of grey wolves left in the United States, and "they still occupy less than 5 percent of their ancient home range." Lydia Millet sums it up so well:

A unified wolf-recovery plan for the nation is required. Not only do wolves play an important role in keeping wilderness wild, but they were here long before we were, and deserve to remain. Not for nothing was the environmentalist Aldo Leopold transformed by the sight of a "fierce green fire" in a dying wolf's eyes.

The threat that wolves pose to domesticated animals is easy to eliminate: put domesticated animals indoors. This should be the first step in a unified wolf-recovery plan. If cattle and other livestock are house indoors in the United States, at least 200,000 wolves should be allowed to repopulate their ancient home range. What a beautiful sight this would be! When wolves are restored in large numbers, this has a trophic cascading effect throughout an entire ecosystem. Plants, animals, insects, birds and even fish proliferate in much greater diversity and abundance (Wolves Increase Biodiversity And Greatly Benefit The Ecosystems They Inhabit).

India holds over half of the world's tiger population (Current Status of Tiger in India), and at times they kill domesticated animals that roam freely outdoors (Tigers kill 15 domestic animals in Amreli district, villagers panic-stricken). Likewise, the threat that tigers pose to domesticated animals is easy to eliminate: put domesticated animals indoors.

Wolves and tigers, along with many other wild carnivores, deserve a home free of humans and their domesticated animals. As domesticated animals housed indoors no longer compete for grass with ungulates such as deer, elk, wild goats, moose and bighorn sheep, populations of wild ungulates increase, and wild carnivores have sufficient prey. The restoration and "rewilding" of grasslands and rainforests becomes possible (The Rewilding Institute).

As the productivity of farmland increases, as the need for pastureland diminishes, and as clear lines are drawn between domesticated and wild, more and more land can be returned to the wild as pristine ecosystems untouched by human activity. Wild animals should not be relegated only to circuses, zoos and parks. Wildlife belongs in the wild (Born Free: Keep Wildlife in the Wild).

Some argue quite logically that we should all become vegetarian, better yet, vegan (The Facts and Why Vegan? and The Myth of High-Protein Diets). But how do we bring about such large-scale change in eating habits? In the developed world, a high tax should be placed on all meat and dairy products. But then there is the fact that cattle and other ruminants can produce food from waste biomass and co-cropped biomass that humans are in no way equipped to digest. Since we insist that the only waste or co-cropped biomass be used to feed cattle, not an additional hectare of farmland should ever be used. All must take place within the framework of existing farmland: otherwise no cattle. How this can be accomplished will become more apparent in the sections that follow.

Many poor people throughout the world would be seriously deprived of nutrients, if not for the products derived from cattle and other ruminants. Also a cow is a prodigious producer of waste. Its waste can be transformed into highly valuable feed for other creatures that serve as meat for human consumption. A lot can cascade down from cattle waste, as shown in this slide.

Cowboys typically focus only on raising cows. They notoriously take from the land, while giving back absolutely nothing in return. As previously noted, they take advantage of grasslands and rainforests which they destroyed in the name of greed and easy money. They neglect how to transform the waste of the cow and how its transformed waste could cascade down to plants and other animals. They do not co-crop, and they typically do little co-raising. If they did, they would no longer be called cowboys but farmers.

"The capture of the West's landscape by the cattle industry may be one of the biggest ongoing mistakes of our history," says Wuerthner. And for what? To protect a mythological hero called the cowboy. Time to smash this idol of the American West and move on" (The Cowboy and the Desertification of the West). Also see: Dispelling the Cowboy Myth.

In Japan there are not many cowboys. Japan uses only 1.4% of its agricultural land as pasture. Cattle for the most part are raised intensively indoors on bedding in close-sided barns. Japanese farmers "frequently combine rice cultivation, vegetable growing and beef cattle production" (Modern Japanese Production Systems). Such combinations are precisely what are needed in beef cattle production. However, the Japanese must make sure that every cow raised intensively indoors on bedding has ample space (at least 12 square meters).

CASCADING CYCLES OF WASTE TRANSFORMATION

We have examined how the raising of cows, pigs and chickens can be greatly simplified by means of the application of same set of waste transformation technologies. But the raising of cows, pigs and chickens are open systems capable of high levels of integration. The essence of value creation "lies in the opportunity to extract value from products and materials by cascading them through other applications" (The circular model - an overview).

For example, larvae and red worms grown on cow feces can be fed to young pigs. Larvae and red worms grown on pig feces can be fed to chickens. Larvae and red worms grown on chicken droppings can be fed to catfish, tilapia and shrimp. Or larvae and worms grown on pig feces can be fed to chickens, and larvae and worms grown on chicken droppings can be fed back to pigs. If cheese is made from cow's milk, the cow can make another valuable contribution to the growth of the pig: whey makes a great feed for pigs (Effect of liquid whey feeding on fecal microbiota of mature and growing pigs). Fresh chickens dropping can be fermented along with other biomass and fed to cows or pigs.

Vermicompost derived from the waste of pigs, chickens and cows, can be used to fertilize an endless number of plants, and the same vermicompost can even be routed to aquaculture. The addition of vermicompost to shrimp pond water is already taking place in the Mekong. This practice was introduced into Vietnam by the Japanese, and it has been proven to be highly successful. Larval residue can even be fed to shrimp. When shrimp eat BSF larval residue, it can result "in similar performance as with regular prawn feed, with better economic returns" (State-of-the-art on use of insects as animal feed).

Catfish and shrimp pond water rich in nutrients can be used to a limited extent to irrigate and fertilize rice fields. When green rice straw is fermented and fed to cows, cascading cycles of waste transformation -from cow to pig to chicken to fish - end up right back where they started from, as illustrated in slide three. Pond water can also be used to grow duckweed or water spinach. Duckweed along with BSF larvae constitutes a total diet for tilapia. Catfish, tilapia and shrimp byproducts can be fermented and fed to pigs and chickens. BSF larvae, earthworms and duckweed can be fed to frogs in an integrated farming system (Fly larvae, earthworms and duckweed as feeds for frogs in an integrated farming system). In another study on the cultivation of the slider turtles, the turtles grew best when fed a combination of larvae and duckweed (Diet Mixing: Nonadditive Interactions of Diet Items in an Omnivorous Freshwater Turtle). The possibilities and combinations here are endless.

The farmer should learn to manage relationships between living systems that mutually support one another. *The ability of a plant, animal, bird or fish to enhance the growth of something else becomes paramount in agricultural planning.* This approach enables the farmer to have a highly diversified basket of products that protects against market fluctuations and assures a predictable and steady stream of income.

Through plant and animal diversification, the farmer's profitability per hectare can be five to ten times higher per hectare than that of a conventional farmer. The highest level of productivity, the greatest number of jobs, and the greatest environment benefit are achieved when animal and crop production systems are combined. "Full integration of livestock and cropping systems may help in slowing or reversing some of the detrimental environmental and sustainability issues associated with agriculture" (Toward a sustainable agriculture). A pig, chicken or cow should be valued not only for the food it provides. It should also be valued as one of the best things we've got in disposing of certain types of waste at the local level. And its waste should be valued as one of the best things we've got in the production of certain feeds and fertilizers. It's intense. It's circular. It does not allow for, or need, external inputs.

"At the beginning of the 20th century, the average farm [in the US] grew five or more crop types (and usually with a mixture of crops and livestock production); at the beginning of the 21st century, the average farm was growing only one type of crop" (Industrial Crop Production). This trend toward mono-cropping and large-scale factory farming has proven to be an utter failure and must be reversed as quickly as possible.

High levels of productivity can be achieved not by means by over-crowding, antibiotics, growth hormones, chemical fertilizers, agro-chemicals, mono-cropping or mono-raising. Instead high levels of productivity are achieved by employing multiple waste transformation methods in conjunction with multiple co-cropping and co-raising systems that all reduce cost and generate income. *If we do not learn to diversify and closely integrate farming systems, if we do not learn how to use space efficiently, if we do* not learn how to *"think in cascades," we fail to understand what value creation and sustainability are all about.* But is this not a bit too complicated for small farmers in developing countries to handle?

FARMERS MIGHT SPECIALIZE

Some farmers will not be able to achieve high levels of integration. They must specialize, and according to one model of specialization put forward by Michael Wood of the non-profit filanthope, they might closely cooperate with one another in the free exchange of feed and fertilizer. For example, a farmer with a mixed crop of coffee, bananas and perennial peanut might ferment coffee pulp, banana stem and peanut grass, and supply them as feed to a farmer growing pigs and chickens. The pig and chicken farmer might in turn provide vermicompost enriched with biochar to this mixed-crop farmer. Here nothing is invoiced. It's simply a gift exchange between farmers. Why does everything within agriculture have to be monetized?

Specialization could go further. For example, if a farmer raising pigs and chickens finds it difficult to buy and seed biopods, she might call upon a small-scale insect farmer to help out. The insect farmer would provide seeded biopods free-of-charge. The pig and chicken farmer would only have to collect fecal material, place it in biopods located right next to her pens, and stir. Once a week the insect farmer would collect and buy live larvae. BSF larvae do not emerge quickly as adults and are easy to store in loose rice hulls at tropical temperatures for up to two weeks.

When biopods would fill up with residue, the insect farmer would replace old pods with empty ones seeded with larvae. The insect farmer might sell BSF residue to a small-scale worm or shrimp farmer. The worm farmer might sell vermicompost to vegetable farmers – vermicompost which, together with thermophilic compost and biochar, eliminates the use of chemical fertilizers. When insect and worm farmers sell their products to shrimp and catfish farmers, they should learn to sell preferentially to farmers not engaged in the horrible practice of discharging filthy effluent and sludge into nearby streams and rivers. But why should they be so concerned about what happens to their products?

The answer is obvious: they do not want to miss out on the availability of nutrients next time cascading cycles of waste transformation come their way. *Farmers who specialize need other farmers who specialize. Without such interdependency, sustainability can never be achieved.*

CO-OPS COULD MAKE A DIFFERENCE

Another way to attain a high degree of specialization would be through co-operatives. In Vietnam pigs farmers, for example, need to form co-ops.

Pig farms in Vietnam are relatively small. Small traders typically assemble pigs from small farms and pass them on to larger traders who in turn pass them on to even larger traders. By the time pig products make it to consumers, they pass through too many hands. In the Central Highlands of Vietnam, the marketing margin from farm to consumer is more than 75% of the farm-gate price (Current Status and Prospects for the Pig Sector in Viet Nam). Small pig farmers do not make enough money, consumers pay too much money, while middlemen, who might have pigs in their possession for only a few hours, make a fortune.

On the purchasing side, a co-op could buy most of what is needed by hundreds of small farmers and greatly increase their purchasing power. On the selling side, a co-op could bundle products under a common brand name. It could certify to consumers that all is grown in a sustainable, safe and humane manner. For example, the consumer would be able to buy pork of an exceptional quality and taste at a price, we suggest, less than that of conventional pork that is typically tasteless and unfit for human consumption.

A co-op could operate a black soldier fly breeding center and could make seeded biopods available to its members. A co-op could operate a vermicomposting facility to process the residue of these biopods. A co-op could become a major producer of larvae, worms and vermicompost - all to be utilized within the co-op itself. A co-op could operate its own pig breeding center that would supply weaned piglets from healthy sows that never saw gestation crates, concrete floors or antibiotics. Co-op members would not have to bother with artificial insemination, or caring for sows and piglets in maternity pens. At the pig breeding center, the weaning age could be extended, and live coverage of females could take place. A co-op could even operate its own slaughterhouse. By means of co-ops, small farmers could compete in a forceful manner with large conglomerates, and they could eventually shut them down. Yes, shutting down factory farms should be a top priority.

Some co-ops might work exclusively with small farmers and limit the number of pigs grown by each member. This would be an effective way of increasing investment, distributing wealth and reducing poverty throughout rural Vietnam. Large funding organizations could play an important role in helping to organize and staff co-operatives. Other co-ops centered on the raising of chickens, cows, rabbits, shrimp or fish could be formed.

Many people will object saying that it's not easy to organize co-ops in Vietnam. They're right. Many attempts to organize co-ops in Vietnam have failed. But it's not so hard to figure out where the problem lies. For the most part it lies with getting men to work together in a harmonious and responsible manner.

In Vietnam men generally lack attention to detail and the high level of responsibility displayed by women. This is clearly the case at the household level in Vietnam, where money, by necessity, is managed predominantly by women. Generally Vietnamese women do not drink and gamble, and they have a much better ability to care for animals than men. The care of animals should only be entrusted to people who love animals and are deeply devoted to making them happy.

In Vietnam women make up 53% of the farming population. They courageously hold dual responsibility for farm and household management. They are actively involved in small livestock production. Agricultural products are processed and marketed mainly by women (Vietnam).

We suggest that all positions of leadership within co-ops should be staffed by women. Leadership and membership positions within co-ops could be assigned exclusively to women. Chickens and rabbits are easier to manage than pigs, and hundreds of chicken and rabbit co-ops consisting only of female members could become a powerful force within agriculture in Vietnam.

THE RECYCLING OF HUMAN WASTE

When farmers become skilled at transforming agricultural waste, they will soon discover that there is not enough of it to meet their needs. So they will be forced to turn to human waste and to biodegradable household waste to make up for the shortfall. First let us look at the recycling of human waste.

On a yearly basis a human produces roughly 500 liters of urine and 50 liters of feces. These two products contain enough nutrients to grow most of the plants that a human needs as food. But instead of utilizing these 550 liters as a resource, most people in the developed world mix them with about 15,000 liters of water, and all is flushed down the toilet. This end-of-pipe solution recycles nothing. It takes valuable resources and transforms them into pollutants.

In the developed world, human waste is mixed with drinking-quality water, and at times, this foul water is converted back into drinking water. The environmental and financial cost of doing this is huge. This practice is absurd and should not be held up as a model for Vietnam.

Flushing human waste to a modern sewage plant creates ideal conditions for the proliferation of antibiotic-resistant pathogens. "By gathering bacteria, including human pathogens, together in sewage treatment plants, we have unwittingly created ideal incubators for creating antibiotic-resistant pathogens and spreading them throughout the environment" (The Poop on Superbugs). The American Academy of Microbiology calls sludge from sewage treatment "a hotbed for the development of antibiotic resistance. When dewatered sludge is applied as fertilizer to agricultural land there is a risk of introducing both antibiotics and resistant strains into the food supply."

For example, Stenotrophomonas, a pathogen resistant to all forms of antibiotics (including all carbapenems), has turned up in sewage sludge compost being sold in Athens-Clark county, Georgia (Sewage Sludge: A Pool Of Pathogens). This compost "is now trucked to urban gardens, baseball fields, parks and school grounds; contaminating the soil children play on and the food grown at home." But antibiotic-resistant pathogens are only one part of this sordid story.

Far more alarming is the fact that wastewater treatment systems are also incubators and distributors of prions. Prions are misfolded proteins that induce properly folded proteins to misfold in a highly lethal chain reaction. "All known prion diseases, collectively called transmissible spongiform encephalopathies (TSEs), are untreatable and fatal" (Prion). They are also resistant to most efforts to eradicate them, such as proteases, thermophilic composting, boiling, ultraviolet light, radiation and formalin treatments.

The Nobel laureate Stanley Prusiner writes "The brain diseases caused by prions includes Alzheimer's, Parkinson's, Huntington's, amyotrophic lateral sclerosis (Lou Gehrig's disease), and other disorders known as frontotemporal dementias." The alarming rise in the occurrence of these diseases is linked to sewage sludge disposal: "Reckless sewage disposal policies and practices alone are putting billions of innocent people in the crossfire right now. Entire watersheds are endangered thanks to a deadly pathogen [the prion] that migrates, mutates and multiplies (Sewage Mismanagement Killing Millions Of People Annually). In Alzheimer's Disease Epidemic Fueled By Mismanaged Sewage, Contaminated Watersheds, Gary Chandler explains:

If a single person with prion disease discharges bodily fluids or feces into a public sewer system, that sewage system is permanently infected, and the amount of contamination will multiply and intensify

daily. Everything discharged from that sewage system—reclaimed water and biosolids—can spread the contamination even further.

Sewage treatment plants do not inactivate prions or remove them from effluent and sludge. The United States generates annually about 7.1 million tons of sewage sludge, and 55% of this sludge is used as a fertilizer or soil amendment. Sewage companies often pay farmers to take their contaminated sludge. When farmers fertilize crops with prion-infested sewage sludge or reclaimed sewage water, prions are taken up by these plants, potentially contaminating any animal or human that might eat them. Dr. Claudio Soto confirms that "plants uptake prions and are infectious and deadly to those who consume such plants."

Some ranchers fertilize pastures with sewage sludge. When they do so, prions are taken up by grass and other plants. As we have noted previously, cows, in addition to grass, also eat dirt. If this dirt contains sewage sludge with prions, cows are directly ingesting prions. Forty years after sewage sludge is spread on a field, cows can still become infected with prions. Prions from sewage sludge have turned up in cow and human milk (Could Prions Be In Milk And Dairy? – Yes). Chandler sums it up so well: "Thanks to questionable policymakers and profiteers, you are eating and drinking from your neighbor's toilet–and the toilets at the local nursing home and hospital. We might as well dump sewage out of windows again."

Certain forms of wildlife are also put at grave risk wherever sewage sludge is dumped. Members of the cervid family (deer, elk and moose) are being decimated by a prion disease called chronic wasting disease (CWD). CWD prions are taken up by grass plants (Grass Plants Bind, Retain, Uptake and Transport Infectious Prions), and when these plants are eaten by animals, animals become infected ('Surprising' Discovery Made About Chronic Wasting Disease). CWD prions appear in the saliva, mucous, urine, feces and remains of infected animals, all of which can pass on the disease to more plants and animals. CWD has decimated herds in 23 states in the United States as well as in two provinces in Canada. In Saskatchewan, where a lot of sewage sludge is dumped, populations of deer, elk and moose are particularly hard hit.

Wastewater going to sewage plants inevitably contains many other pollutants: flame retardants, heavy metals, polycyclic aromatic hydrocarbons, radioactive materials, antibiotics, sedatives, sex hormones, steroids, plus many other problematic substances and drugs. At times people flush pharmaceuticals down the toilet. Also a lot of drugs are not properly metabolized within the human body and end up in human excreta. Even the best sewage treatment plants fail to remove pharmaceuticals from the supposedly clean water they discharge. These drugs make it into streams and rivers, and "can alter the biology and behavior of fish and other marine animals" (Medicines flushed down toilets hurting fish: study). Here we might be dealing with pharmaceuticals in extremely low concentrations – a mere two parts per billion. That's all it took to significantly alter the behavior of the wild European perch used in the above study.

Sewage sludge discharged near Hanoi contains high concentrations of heavy metals such as arsenic, cadmium, chromium, lead, copper and zinc. It also contains high levels of polycyclic aromatic hydrocarbons – "greater than those reported in sewage sludge from other countries" (Heavy metals and polycyclic aromatic hydrocarbons in municipal sewage sludge from a river in highly urbanized metropolitan area in Hanoi, Vietnam). Such sludge is unfit to be used as fertilizer. It also poses a risk when landfilled.

Some municipalities in Vietnam recognize the danger of using sewage sludge as a fertilizer, as well as the danger of dumping it in landfill. So they set about incinerating it. But all they end up doing is replacing one horrendous problem with another. Some incinerators in Vietnam emit high levels of dioxins, some at 5,000 times the safe limit. "Ho Chi Minh City has the worst dioxin pollution caused by the disposal of sewage sludge from incinerators" (Study finds large dioxin emissions from Vietnam's waste treatment plants). More on incinerators in the next section of this paper.

The majority of urban households in Vietnam have septic tanks (Total Flow of N and P in Vietnam Urban Wastes). Yet most septic tanks are improperly designed and constructed. Most are constructed out of brick and concrete, some without bottoms. "Even if they are built with a bottom, bricks and concrete crumble after 3-5 years with the consequence of fecal matters entering constantly into the soil and the groundwater" (Report on research on vacuum sewer collection system).

Most septic tanks in Vietnam are seldom cleaned out. When they are cleaned out, the disposal of sludge is not properly regulated. Sludge from septic tanks is dumped at times on open land or in lakes, streams, canals and rivers (VIETNAM WATER AND SANITATION SECTOR ASSESSMENT REPORT). Effluent from septic tanks for the most part combines with storm water and flows untreated into water bodies. Many hospitals in Vietnam do not have proper sewage and wastewater treatment stations. Their wastewater is discharged into the same drainage systems used by household septic tanks. Even if hospitals might have a proper sewage treatment system, this would not stop the spread of prions.

Septic tanks and septic tank drainage systems also provide an ideal home for antibiotic resistant pathogens (Antibiotic Resistance in Septic Effluent). One antibiotic resistant pathogen associated with human waste, Shigella sonnei, has become the major cause of dysentery in Vietnam. "The bacterium probably originated in a densely populated area of Ho Chi Minh City and spread by the canal system" (Rapid evolution behind Shigella's rise).

Under the anaerobic conditions of septic tanks, both hydrogen sulfide and methane are formed. Hydrogen sulfide (H_2S) is a pungent, explosive, corrosive and highly toxic gas. "The toxicity of H_2S is comparable with that of carbon monoxide" (Hydrogen Sulfide). Within septic tanks, "nitrates and organic nitrogen compounds are reduced to ammonia" (Septic Tank), and phosphates stay/become soluble and mobilized. When nitrates and phosphates overflow into the environment, they "can trigger prolific plant growth including algal blooms, which can also include blooms of potentially toxic cyanobacteria." Lakes, streams, rivers and coastal areas are often polluted by septic tank runoff. Septic tank effluent is causing massive fish and turtle die-offs in certain parts of the United States (Long Island Sees a Crisis as It Floats to the Surface).

Most septic tanks in use within the city of Dalat are environmental disasters. In Dalat septic tank effluent pollutes soil and groundwater, it spreads antibiotic resistant pathogens, and it makes a significant contribution to the pollution of Xuan Huong Lake and other bodies of water. In dry season the stench from open ditches and canals can be unbearable. Even in wet season, people eating in restaurants on busy Bui Thi Xuan Street have to put up with the stench of septic tank effluent, mostly the stench of ammonia and hydrogen sulfide.

Rats and mice find endless shelter in subterranean sewer and septic tank drainage systems. They come out at night from these drainage systems to feed on commingled household and restaurant waste left on sidewalks. Huge rats are commonly seen in all major cities in Vietnam feeding on sidewalk garbage. “So many rats are found in districts in the city because there is too much food and garbage lying out in the open” (Rats becoming a serious menace in HCMC). Many restaurants pour watery slop into drainage systems to the delight of rats therein. In and around sewer and septic lines, mice and rats have everything they need to thrive in large numbers: food, water and shelter (Methods of Sewer Rat Control). It’s rodent paradise, and a grave menace to human health.

Rodents transmit many different kinds of diseases to humans via droppings, urine, bites, scratches and fleas. In Vietnam these diseases include the Hantavirus (HCM City: Sewer-rats carrying the virus that causes kidney failure), rat hepatitis E virus (Characterization of Full Genome of Rat Hepatitis E Virus Strain from Vietnam), Leptospirosis (Leptospira infection in rats in the Mekong Delta of Vietnam), plague (WHO), rat-bite fever (Inappropriate Footwear and Rat-Bite Fever in an International Traveler) and Salmonellosis (Prevalence of Salmonella spp. in Rice-Field Rats in the Mekong Delta, Vietnam). Sometimes rats make it into houses through flush toilets (images). Tiny aerosols of the dried out urine and feces of rodents can transmit disease within a home.

Urban drainage systems easily become overloaded during heavy rains. When this happens, they discharge human and rat waste onto streets, sidewalks and sometimes into houses. People on foot and on motorbikes often get splashed and drenched in a disgusting cocktail of human and rat waste. Take a look at these pictures of flooding in HCMC: Saigonese struggle with severe flooding after rain, again. “Flooding disperses the wastewater from sewage everywhere, which causes water pollution, epidemic diseases, damage to houses and instruments” (Urban flooding in Ho Chi Minh City). Drainage systems in many cities in Vietnam are old and not properly maintained. Some are filled with garbage (VIETNAM: Dozens killed by flooding). Here you see what flooding looks like in Hanoi and Hue. As a result of climate change, such flooding will get far worse.

Less than 20% of rural households have latrines that meet “sanitation standards in construction, use and maintenance.” Some households make use of nothing other than a hole in the ground. Open defecation is still a problem. “According to the UN, some 10 million people in Vietnam continue to practice open defecation. Some defecate in rivers and ponds, the same water sources they use for cooking, cleaning and bathing” (Vietnam: Teaching new sanitation habits). Open defecation is not confined to rural Vietnam. Right within district one of Dalat, open defecation takes place.

Hoping to improve upon sanitation practices in Vietnam, some advocate routing human waste to biodigesters. But if continuously-fed biodigesters are operated at mesophilic temperatures, antibiotic-resistant pathogens easily survive and contaminate both effluent and sludge. No biodigester, at mesophilic or thermophilic temperatures, can denature prions.

Also in the biodigestion of human waste, we see roughly the same level of inefficiency that we saw in the biodigestion of pig waste. Most NPK excreted by a human is in the form of urine, and since the C:N ratio of human feces is well below 30:1, none of the urine is transformed into methane. Then a long string of other inefficiencies follow.

When 50 liters of human feces are mixed with 15,500 liters of water and urine, feces represents about 0.323% of the total mix. A biodigester transforms into methane only volatile solids within human feces. Only about 26% of human feces consist of volatile solids. So the figure of 0.323% drops down to 0.084%. Only about 45% of the volatile solids get converted into biogas. So the figure of 0.084% drops down to about 0.038%. Biodigesters leak, and if we use a leakage number of 12.5%, the figure of 0.038% drops to 0.033%. Finally the biogas that makes into the stove contains at best about 70% methane. The rest is mostly carbon dioxide. So the figure of 0.033% drops down to 0.023%. This equates to a mere 230 parts per million.

So much effort is expended in the transformation of so little waste. Transformations that could be taking place at much higher levels within the hierarchy of waste are overlooked, and consequently a lot of money is lost. If biodigester slurry is applied to the land to fertilize crops, it is generally not stored and applied in a timely manner according to crop needs. During storage and land application, a large percentage of plant nutrients escape the system and never make it into the plants they are meant to fertilize.

Then there is the huge amount of fresh water required for flushing toilets - up to a third of the water used within a home in the developed world. Toilets often leak: "water leaks account for approximately 14% of all water use in the average American home, and the toilet is one of the most likely places to find them" (Toilets). At a time when fresh water throughout the planet is becoming an exceedingly scarce resource, we can ill afford to waste water on such a grand scale. Roughly 2.5% of the water on our planet is fresh. Yet only about 1% of this 2.5% is accessible and available. Drought-stricken California would conserve a lot of water and money if it stopped using water to flush toilets and urinals.

"In much of the developing world, clean water is either hard to come by or a commodity that requires laborious work or significant currency to obtain" (Freshwater Crisis). According to the United Nations, "By 2025, an estimated 1.8 billion people will live in areas plagued by water scarcity, with two-thirds of the world's population living in water-stressed regions as a result of use, growth, and climate change." According to recent satellite data coming in from NASA, "The world's largest underground aquifers – a source of fresh water for hundreds of millions of people — are being depleted at alarming rates"(New NASA data show how the world is running out of water).

Previously we stated that flushing the floor of a pig pen can be a significant vector for the airborne transmission of bacterial and viral diseases. The same applies, perhaps even more so, to the flushing of toilets (The potential role of toilets as a vector for transmission of infectious disease and Microbiological Hazards of Household Toilets: Droplet Production and the Fate of Residual Organisms).

Flushing a toilet releases into the air invisible droplets of water, some as small as micron or two in diameter. These droplets can harbor pathogenic bacteria and viruses, as well as prions. Urine and feces are easily aerosolized when a toilet is flushed. Feces might contain antibiotic resistant pathogens such as MRSA, Salmonella, E. coli, Clostridium difficile, Shigella and so forth (Multidrug-resistant Shigellosis Spreading in the United States). Both urine and feces might contain prions. Some pathogens can survive on surfaces within biofilm for weeks or even months after a toilet is flushed. Prions within biofilm remain intact indefinitely. The easy spread of Clostridium difficile in hospitals is linked to flushing toilets, especially lidless toilets (Flush with Germs: Lidless Toilets Spread C difficile).

"Toilet aerosolization was the key factor in spreading the 2003 SARS epidemic around the world" (Solving Indoor Airborne Disease Transmission Problems). Viral bioaerosols can persist for as many as seven flushings following the initial contamination of a toilet. "As has been shown, hundreds to thousands of potentially infectious bioaerosol particles, capable of remaining airborne for extended periods and migrating with air currents, may be generated in a single flush of a toilet contaminated with these organisms" (Aerosol Generation by Modern Flush Toilets).

Some describe toilet flushes as "explosive germ-launching events." People and surfaces get covered in what is called a "fecal veneer." Then there is the splash back of larger drops of water that contaminate toilet seat, toilet lid and the surrounding floor. Even when a flush toilet is not being flushed, splash back onto a user during defecation can take place.

Because flush toilets are so filthy and unsanitary, toxic chemicals are commonly used to sanitize them. "Many toilet bowl cleaners are often highly caustic and form toxic gases when mixed with water. They can contain ammonium chloride, a corrosive; 1,4-dichlorobenzine, a carcinogenic pesticide which can cause liver and kidney damage; hydrochloric acid, whose vapors can cause coughing and breathing difficulties; and sodium dichloroisocyanurate dihydrate which is a severe eye, skin and respiratory irritant, which can form carcinogenic chlorine gas. Sulfate-based products containing sodium sulfate or sodium bisulfate may cause asthmatic attacks" (Guide to Less Toxic Products).

These are just a few of the many toxic chemicals used to clean conventional flush toilets. When cleaning a flush toilet, one should wear gloves and safety goggles. One must also make sure that the bathroom is properly ventilated. When a toilet bowl filled with toxic chemicals gets flushed, these chemicals also get aerosolized and pollute the air within a bathroom. The chemicals that make it down the drain usually end up polluting surface water, groundwater and soil.

Therefore to improve standards of basic human hygiene, to remedy huge environmental problems, to conserve precious water and to be in a position to derive significant value from human waste, we suggest that toilets use not a drop of water. There are many ways, of course, to construct a dry toilet. But for widespread use among the poor, it's got to be simple and low-cost.

Within the human body urine and feces are produced and stored separately, they are excreted separately, and insofar as possible, they should be contained and processed separately. Not allowing urine and feces to mix reduces ammonia emissions, it gives more processing options, and it generally allows for transformations at higher levels.

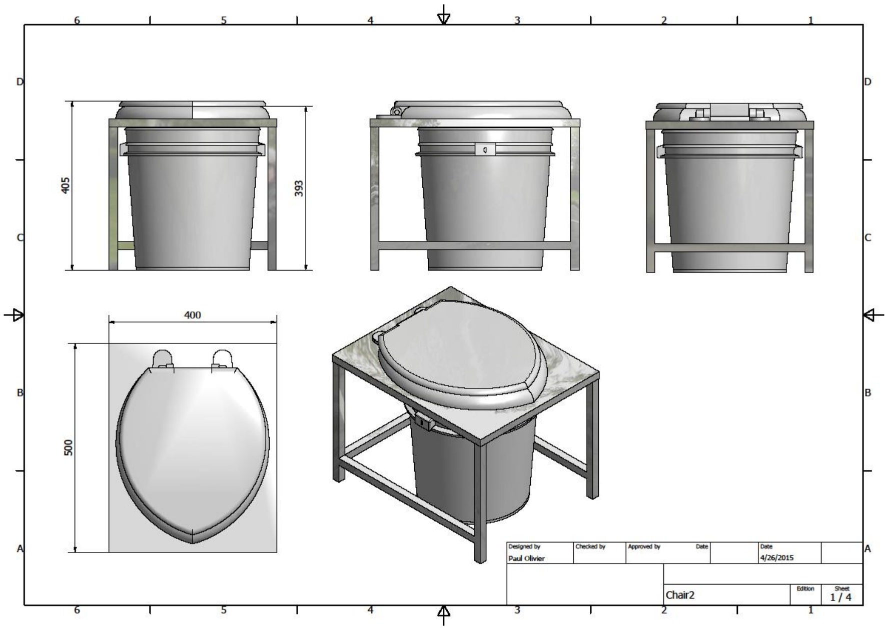
Some dry toilets have two inlets for simultaneous use: one for urine and the other for feces. David Auerbach of Sanergy has a beautiful design of just such a urine-diverting dry toilet (UDDT). His toilet is also a squatting toilet (video).

But it's not necessary that a dry toilet have two inlets for simultaneous use. Most urine is excreted apart from defecation and can be easily collected in urinals. If possible, an effort can be made to urinate prior to defecation. Even if some urine is excreted during defecation, this is not a problem for a properly maintained feces container. A small amount of urine does not contaminate feces or limit the number of options available in processing it.

Also there's a small problem with a squatting toilet. Relative to the level at which the user squats, waste receptacles have to be positioned below this point. However in the case of a pedestal toilet, the entire toilet with waste receptacles can be conveniently situated at ground or floor level. If a platform does not have to be constructed to elevate the user, the toilet becomes easier and cheaper to construct and install. If a hole does not have to be dug in the floor to receive a waste receptacle, a lot more flexibility is achieved in locating, re-locating and cleaning the toilet.

In the toilet we propose, not a centimeter of pipe, hose or conduit is needed - to, from or within the toilet. A dry toilet can be constructed using only three items:

1. an ordinary 5-gallon or 20-liter bucket (commonly available second-hand in Vietnam),
2. a stainless steel stool weighing about 3.2 kg,
3. a conventional toilet seat with lid and fasteners (made in Vietnam by several manufacturers).



For more design detail, see these jpegs: 001, 002, 003, 004, 005, 006, 007, 008, 009, 010, 011, 012, 013, and 014. Here are pdf drawings of the same: 001 and 002. Here are some photos of the first prototype: 001, 002, 003, 004, 005 and 006.

We propose a short bucket of a height of about 36 cm's (003), not a tall barrel. We view the bucket not as final waste processing vessel, but only as a means of containing waste for a limited period of time. Since the bucket is short, a platform is not needed to elevate the user, as in the case of a barrel.

With a bucket height of 36 cm's, the toilet seat situates at a height of about 38 cm's above floor level - a height less than most pedestal flush toilets. Some bucket toilets are really simple. They have no stool (Make a Twin Bucket Toilet). The toilet seat snaps directly onto the bucket. But a stool, we believe, is important in providing stability to the toilet.

In the construction of a stool, wood is not good (011). Wood is porous, absorbent and hard to clean. We suggest that a toilet stool be constructed out of stainless steel so that it can be easily cleaned. If high-quality stainless steel such as 304 is used to construct the stool, the stool will never rust or corrode.

In jpegs 001 and 002, and in picture 003, we see that the top of the stool has a ring that extends down into the bucket by about two centimeters. The ring makes it easy to align stool and bucket. Leakage or spillage between bucket and stool is impossible. Also, the inner edge of the toilet seat extends down into the ring of the stool by about 5 mm. Similarly leakage or spillage through stool and lid is impossible. When it comes time to empty the bucket, the stool is light and can be lifted from off the bucket. The weight of the user does not bear down upon the bucket, only on the metal stool.

The toilet seat and lid are fastened to the stool by two plastic fasteners which are supplied with every conventional toilet seat/lid assembly (jpeg 013). The stool can have a slightly inclined back, more chair than stool (015, 016, 017 and 018).

The one toilet can be equipped with two buckets that can be swapped in and out according to need: one bucket predominantly for feces, and the other exclusively for urine.

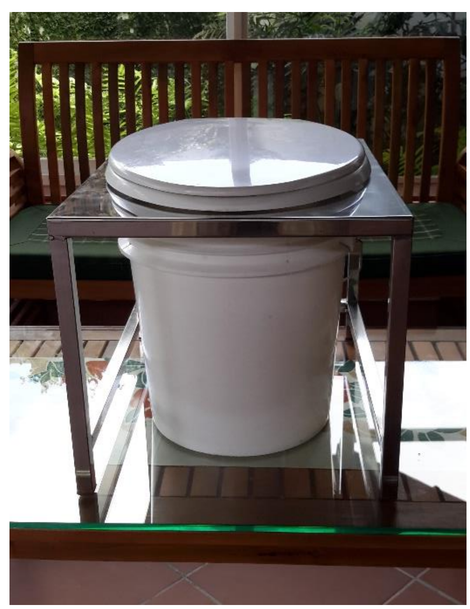
When the toilet is positioned over a urine bucket, the toilet functions quite nicely as a urinal for women. Toilet paper used in conjunction with urination should be deposited in the feces bucket. A bit of used vegetable oil can be added to the urine bucket to serve as a sealant and prevent the escape of smelly ammonia.

Another way to suppress odor from urine is to add to the urine bucket about 8 ml of ordinary household vinegar (about a half tablespoon) per liter of urine. The addition of vinegar suppresses the formation and emission of smelly ammonia. Urine acquires a mild and quite pleasant vinegar smell. The decision to add used vegetable oil or vinegar to the urine bucket depends on how the urine is subsequently processed.

A feces bucket under normal household use does not have to be emptied out more than once each week or two. For easy clean-out, the walls of a feces bucket can be lined with a thin layer of used cardboard, with a sheet or two of newspaper or, in an affluent setting, with 100% unbleached parchment or kraft paper. Plastic bags should never be used. The bucket liner should be folded over the top of the bucket where it is held in place by the stool ring.

The clean-out of feces and urine buckets should be done using a probiotic liquid. This prevents the accumulation of biofilm and knocks out odor. In terms of basic human hygiene, a dry toilet greatly outperforms a flush toilet.

The toilet we propose is portable. It can be brought outdoors for rapid and easy cleaning. It can be situated anywhere that privacy permits: in a bathroom or even temporarily in a bedroom. A urinal in a bedroom can be quite convenient for the elderly and infirm. In a disaster-stricken area, this bucket toilet becomes immediately functional. It can be situated behind a partition screen or privacy curtain within a tent.



With a 304 stainless steel stool as shown here, this toilet costs about $25. Since it costs so little, a household could be equipped with two toilets: one with a feces bucket and the other with a urine bucket. A smaller version of this toilet can be designed for children.

In hospitals and nursing homes, dry toilets are absolutely essential. If flush toilets are used in these disease-infested settings, bacteria, viruses and prions inevitably get aerosolized. The aerosolized prion is one of many ways in which caregivers become infected with prions. These prions (TSE's) are by definition transmissible. "Caregivers of those with dementia are six times more likely to contract the disease than people who are not caregivers" (Alzheimer's Disease Spreading Faster Via Biosolids, Reclaimed Water).

Imagine further the problems that arise when the waste of someone with prions is flushed with water. The waste of this person increases in volume at least 30-fold. When that person's waste gets flushed along with the watery waste of thousands of other people, the prion problem becomes impossible to fix. Flushing prion-contaminated human waste is reckless and irresponsible.

Of course dry toilets used in hospitals and nursing homes should be far more sophisticated in design than dry toilets used in ordinary healthy households. For example, the toilet seat could be made of stainless steel, and it could be smoothly and seamlessly press-molded into the stainless steel stool top. The combined stool/seat could be sanitized of prions in the same way as surgical instruments. Urine and feces would be allowed to mix in a special waste receptacle made from bio-plastic. The receptacle and its contents would be disposed of at high heat and pressure. Sterilized rice hulls from the parboiling process could be shredded and mixed with biochar to suppress odor within the waste receptacle. A probiotic spray should be applied before and after each use of the toilet.

Some correctly argue against pedestal toilets saying that "the sitting position causes the defecating human to assume a narrow anorectal angle, which may be obstructive and causes difficulty in emptying the bowels" (Defecation postures). This problem can be solved by means of what is called a squatty potty. A squatty potty is a small riser that elevates the legs of the user when seated on a pedestal toilet. It puts the user of the pedestal toilet in a squatting position, as neatly explained in this video.

A pedestal toilet is especially convenient for the elderly or infirm who might find it difficult to squat all the way down to the floor or to stand up from a squatting position (Dizziness or Light-Headedness When Standing Up). Squatting on top of a pedestal toilet is definitely not recommended. It's both dirty and dangerous. When the user squats on top of a pedestal toilet, urine and feces do not always get properly deposited in the toilet, and the user can easily slip and fall off the toilet.

In cultures where anal cleansing using water is the norm, a toilet equipped with a feces bucket could be located in a bathroom or shower-room, where there is easy access to water. Anal cleansing with water should not take place while the user is seated on the toilet. The toilet should not get splashed with filthy water containing fecal material. Well away from the toilet, the poor might use a shallow pan for cleansing, while the more affluent might use a bidet. Anal cleansing should be done with a probiotic soap. Urination, defecation and aqueous anal cleansing are separate activities. They should take place over separate receptacles.

Since a household can easily afford one or more toilets, there is no need to build communal toilets in villages. In most cases, a communal toilet must be enclosed with walls and roof, and therefore it can cost hundreds of US dollars to build. Communal toilets are not very convenient, especially during the night. Sometimes people have to walk long distances to get to them. This makes girls and women potentially vulnerable to physical and sexual assault.

Communal toilets often serve as a vector for the spread of disease. Households do not always have the same standard of hygiene, and they should not share toilets. Each household should have its own toilet or toilets. Each household should be involved in the management of its own waste.

What do healthy households do with the urine and feces they produce? The answer is simple: transform and return every bit of it to agriculture. This, of course, can be done in many different ways. Only a few options in human waste transformation are explained in what follows.

"Human urine contains 88% of excreted N, 67% of excreted P and 73% of excreted K" (Characteristics of urine, feces and greywater). The remainder is in feces. Urine from healthy people is generally sterile and contains few pathogens.

It can be collected from households and brought to a decentralized urine processing facility. Here a small amount of magnesium oxide can be added to urine to produce a crystalline precipitate - mainly magnesium ammonium phosphate hexahydrate ($MgNH_4PO_4\ 6H_2O$) along with smaller amounts of montgomeryite, brucite and epsonite. There is also a magnesium potassium phosphate hexahydrate, a potassium struvite ($MgKPO_46H_2O$). By adding small amounts of soluble magnesium oxide (MgO) to human urine, most of the phosphorous (95-99%) and some of the nitrogen can be recovered as a crystalline precipitate (Sustainable Utilization of human urine in urban areas – Practical Experiences). A good portion of the remaining nitrogen and potassium can be captured by adsorption using zeolite, wollastonite or biochar. If this struvite method is used in processing urine, vinegar should not be added to urine.

MgO can be produced by calcining magnesite rock using gasifier heat. Finely ground magnesite ($MgCO_3$) can be incorporated into biomass pellets. When these pellets are gasified at a temperature of about 700 C, soluble MgO is produced. Biochar pellets containing soluble MgO can then be used for struvite precipitation. When MgO and biochar are used together, struvite precipitates on the surface of the biochar (Nutrients recovery from artificial urine through struvite crystallization and biochar adsorption).

If a small amount of soluble phosphorus produced from bone char is added, all nitrogen can be captured in struvite form (Ammonium nitrogen removal from slurry-type swine wastewater by pretreatment using struvite crystallization for nitrogen control of anaerobic digestion). P-solubilizing bacteria and fungi secrete organic acids strong enough to dissolve struvite and make its magnesium, ammonium, potassium and phosphorus available to plants.

In a rural setting where space is available, it's easy to collect and route human urine to duckweed ponds. The pond shown here processed the urine from a small restaurant in the Mekong. Human urine has an NPK ratio of about 10:1:4. But does this number represent sufficient phosphorus and potassium for healthy duckweed growth?

To reach high levels of protein and rapid growth, duckweed requires relatively high concentrations of nitrogen varying from 20 to 60 mg of N per liter of pond water. By contrast, duckweed can thrive on concentrations of P as low 1.0 mg per liter of pond water. It also does quite well on low concentrations of K (DUCKWEED: A tiny aquatic plant with enormous potential for agriculture and environment and Duckweed - a potential high-protein feed resource for domestic animals and fish). So it's fairly safe to conclude that human urine is not deficient in P or K for vigorous and healthy duckweed growth.

Ammonia in the ionized form (NH_4+) is the preferred substrate for duckweed. So it's best to add a small amount of vinegar to the urine bucket to lower pH. Feces can harbor dangerous pathogens and should not be routed to duckweed ponds. Duckweed removes pharmaceuticals from water as effectively as membrane bio-reactors and activated carbon (Duckweed Uptake of Phosphorus and Five Pharmaceuticals). Duckweed tolerates relatively high salt concentrations, up to about 4,000 mg/liter (Improvement of Detention Ponds with Respect to Salinity).

Another option: the urine bucket can be filled with a mixture of biomass and biochar. Both should be dry and as fine as possible. The nutrients in urine get sorbed and immobilized, just as in the case of pig bedding. A probiotic liquid should be sprayed before and after each use of the toilet in urinal mode. The contents of the urine bucket have no odor. When the urine bucket fills up, it can be emptied into a mesophilic bin. More about mesophilic bins in the next section.

Another variant on this "bedding" concept: no biomass or biochar is placed in the urine bucket. A small amount of household vinegar or used vegetable oil is added to prevent the volatilization of ammonia. When the urine bucket fills up, urine is poured into a mesophilic bin containing a mixture of biomass and biochar. Each time urine is poured in, the contents of the mesophilic bin are stirred. Within about an hour after pouring urine into the bin, there is zero smell. What nature does here is quite amazing. Composting urine is also effective in breaking down many pharmaceuticals.

Fresh urine can be fermented in the urine bucket by lactobacillus cultures derived from sauerkraut brine. This knocks out pathogens, no ammonia or carbon dioxide are released, it stops the harmful decomposition of complex organic matter, and it converts urea into microbial biomass (CONTROLLED FERMENTATION STABILIZING URINE). In this process there are no smelly emissions. "Unique in this microbiological conversion is that the synthesis of humus (oxidative ammonification) is greater than the concurring respiration of organic matter (degradation with smelly release of ammonia)." The "pickled urine" is then added to a compost pile.

Still another way to process source-separated urine. If a small amount of vinegar is added to the urine bucket, there is no ammonia escape, struvite does not form, and the "yuck" factor is gone. Getting rid of odor is quite important during all stages of handling and processing. When the urine bucket fills up, it can be collected and brought to a small decentralized site for processing.

At the processing site, urine can be mixed with a bit of molasses to grow bacteria. Bacteria can double their mass in one to three hours – a rate faster than yeast, fungi or algae. Their crude protein as a percentage of dry cell weight can reach as high as 80% - a percentage higher than yeast, fungi and algae (Production of microbial protein).

The mixture of urine and molasses can be routed to a trickle tower filled with loose biochar as packing material. Biochar provides enormous surface area (several hundred m2 per gram) for the formation of biofilm. Heterotrophic bacteria form on and within the biofilm. Free of nutrients, the spent liquid is allowed to drain away. The biochar loaded with nutrients could be added to a larger fermentation mix involving waste biomass or co-cropped biomass. Or it could be fry-cooked at about 110° C in used vegetable oil to kill pathogens and reduce moisture to less than 6%. Gasifier heat would be used in this fry cooking process. Finally this high-protein meal would be pelleted and sold as animal, poultry or fish feed.

Straw can shredded, treated with urine and fed to cattle. "Treatment of straw with urine, if well organized, may serve as a practical method for small farmers to treat a by-product with another by-product in a sustainable agriculture" (The Need for Improved Utilization of Rice Straw for Ruminants).

Fresh human feces can also be processed in a variety of ways. But there is one method that stands out: fermenting it together with biochar (Development of System for Waterless Collection of Human Excreta by Application of Lactic Acid Fermentation Process in Terra Preta Sanitation System). "Faecal odor is completely suppressed and is replaced by sour smell which is rated as acceptable according to an odor panel, and no E. coli is detected after one week to the end of fermentation." About 10% (w/w) molasses is needed for good fermentation. The addition of neem cake is quite effective in destroying Ascaris round worm eggs. When the feces bucket fills up, its contents can be fed to BSF larvae and their residue to red worms.

But fermenting human feces might be a bit complicated for some households. There's a simpler way. One might add a mixture of biochar and sawdust, or a mixture of biochar and rice hulls, each time the feces bucket is used. Defecation onto a dry surface is ideal. Before and after each use, the surface of the biomass and biochar should be lightly sprayed with a probiotic liquid. The biomass, the biochar and the probiotic spray all work together in eliminating odor. When the feces bucket fills up with solids, it can be emptied into a mesophilic bin reserved only for fecal material. If a lot of fecal material accumulates, it can be composted thermophilically using a compost fleece.

So each household might have both gasifier and dry toilet. Both are compact and portable. With these two items, there are no gas lines in kitchens, and no water lines to and from toilets. As we have seen, biochar from gasifiers can be used in the transformation of both urine and feces. Cooking with a gasifier might not be as convenient as cooking with bottled gas, and using a dry toilet might not be as convenient as using a flush toilet. But the central issue here is sustainability, not convenience.

For more on the recycling of human waste, see this presentation: Empowering the Poor through the Transformation of Human Waste.

We talk a lot about sustainability. But we will never achieve sustainability until we learn to give back to nature in a closed loop everything that she needs to sustain us. Giving back to nature all of the nutrients within our own waste is, perhaps, our first, and most important duty, as citizens of planet Earth.

THE RECYCLING OF HOUSEHOLD WASTE

One of the most problematic and dangerous ways of dealing with solid waste is to bury it in landfill. The soil - the "great placenta of the earth," our sacred Mother who nourishes and sustains us - should never become a depository for waste. Once the soil comes into contact with waste, it becomes just as toxic as the waste that it entombs. Even the highest quality landfill liners break and start leaking within decades of installation. The concept of a "sanitary" landfill does not exist anywhere in the world. Rainfall floods this hole and washes deadly chemicals and microbes into aquifers, streams, rivers and oceans. The landfilling of sewage or septic tank sludge is particularly foolhardy. Anaerobic bacteria proliferate in this watery grave, emitting methane and other greenhouse gases. Instead of solving a problem by land-filling waste, waste management authorities create a problem so big that it becomes impossible to fix.

Another insidious way of dealing of household waste is to dump it in the ocean. “The equivalent of five grocery bags full of plastic rubbish on every foot of every nation's coastline around the globe is how much plastic debris is being dumped into the world's oceans every year”(Eight Million Tons of Plastic Garbage Dumped in Oceans Every Year). Such dumping is “killing huge numbers of seabirds, marine mammals, sea turtles and other creatures while adversely affecting the oceans ecosystems” (World's worst ocean polluters named and shamed as 8 MILLION tons of plastic dumped into sea each year). China is by far the worst offender. Vietnam ranks fourth (5 Asian countries produce majority of plastic in world’s oceans). The United States ranks twentieth (Plastic waste inputs from land into the ocean). Vietnam (alongside Cambodia, Malaysia, Myanmar and Thailand) has yet to accede to any international ocean dumping agreement (Workshop boosts waste dumping regulation in Southeast Asia).

Here in Dalat, every single day of the year, garbage is dumped in, or on the banks of, beautiful Xuan Huong Lake. People often stop their motorbikes on bridges and offload sacks of garbage into drainage canals and streams. Households at times fling sacks of garbage over fences onto neighboring property. Some people dump trash in the middle of streets, in sewage ditches, near Buddhist temples, near government offices, near waterfalls, on empty city lots, wherever they wish. Police seldom take action to deter such selfish and lawless behavior.

Ordinances forbidding the backyard burning of garbage do exist (167-2013), but are seldom enforced. Over and over again in Dalat, for example, especially in dry season, entire neighborhoods get covered in a toxic cloud of dioxins, polycyclic aromatic hydrocarbons, volatile organic compounds, carbon monoxide, hexachlorobenzene, soot, larger particulate matter, plus many other toxins. The ash left over from the burning of waste can contain heavy metals such as mercury, lead, chromium and arsenic. On Oct 28, 2015, Paul Olivier observed waste being burned in green push carts owned by the city. The list of health problems associated with backyard burning is mind-blowing: reproductive problems, fetal damage, developmental problems, suppression of the immune and hormonal systems, asthma, bronchitis, cardiac arrhythmia, high blood pressure, heart attack, liver damage, kidney damage, brain damage and of course, many different types of cancer (Human Health).

To put things in perspective, we must understand that only about a third of the communes in Vietnam are engaged in what is called “waste management.” The household dumping, burying and burning of waste are commonplace throughout the entire country. Even where efforts are made to manage waste, mindless dumping and burning still take place.

It’s not just the backyard burning of garbage that sends Vietnamese to hospitals in large numbers. As landfills run out of space in Vietnam, it often happens that landfills are deliberately set on fire to free up space for more garbage.

But landfill burning still does not create enough space to handle the ever-increasing quantities of garbage generated in Vietnam. So many municipalities think that by burning it in a more controlled manner, they can remedy the situation. This brings us to the problem of the use of incinerators in Vietnam (Should Vietnam Incinerate its Waste?).

Most of the incinerators in use in Vietnam do not meet safety standards for waste treatment, as this newspaper article explains (Burning Waste not answer to pollution). Most small-scale incinerators made in Vietnam waste do not even come close to meeting all meet environmental safety standards (Village incinerators a threat to the environment, residents). Elsewhere we see the most damning appraisal of the situation: "A report on the dioxin situation in Vietnam released in late 2014 showed that many waste treatment plants in Hanoi, HCM City and Hai Duong province had dioxin and dioxin-like toxic substance concentrations in emission and waste water several times to 5,000 times higher than permitted" (All Incinerators in Vietnam produce dioxins: scientist).

When attempts are made to incinerate commingled household waste, a lot of things can go wrong.

Incineration companies in Vietnam often set up picking tables to recover recyclables from commingled household waste. After a rough and imprecise hand-sorting, no separation according to specific gravity takes place. Waste then goes on to trommel screens, vibratory screens and crushers. The fines are screened out and composted, and the oversize goes on to an incinerator.

The compost produced here is about as worthless as sewage sludge, and the only destination for it is landfill. Fly ash and bottom ash from incineration constitute 15% to 20% of the original weight of waste. Fly ash is extremely toxic, more so than bottom ash. These two waste materials are also worthless, and again, the only home for them is landfill. Incineration does a good job of concentrating toxic materials that ultimately end up in landfill. But it does more. It creates pollutants, such as dioxins and dioxin-like compounds (such as furans and PCBs), that didn't exist in the original waste.

To ensure that dioxins are broken down, at least 850 C is required within the furnace of an incinerator. To achieve such high temperatures, auxiliary backup burners, often fueled by oil or natural gas, must be installed. Some small incinerators have to be equipped with high-temperature electrical heating elements. But not all incinerators consistently achieve high temperatures, and when this happens, incinerators start functioning like backyard burn barrels.

Even at high temperatures, there are problems. Nitrogen and oxygen gases can be broken down, giving rise to reactive oxides such as nitrogen oxides. Reactive oxides must be further neutralized with selective catalytic or non-catalytic reduction. If reactive oxides are released into the environment, smog and acid rain are formed.

Flue gases in many incinerators in Vietnam are not free of particulate matter, dioxins, heavy metals, sulfur dioxide, hydrochloric acid and reactive oxides. Electrostatic precipitators and/or baghouse filters are needed to remove particulate matter from flue gases. Limestone slurry must be injected into the flue gas to remove sulfur dioxide. Wastewater from flue gas scrubbing (if flue gas scrubbing does take place) must pass through a wastewater treatment plant. The toxic sludge from wastewater treatment must be landfilled. If electrostatic precipitators, baghouse filters or packed towers should fail through lack of maintenance for even a few hours, vast areas of land in the vicinity of the incinerator get polluted.

An incinerator has recently been installed near Cau Dat, a small village located about 20 kilometers from Dalat. The region of Cau Dat is not only famous for its coffee and tea, but it is also home to one of the few certified organic farms in Vietnam (Organik). The incinerator is located about two kilometers from this organic farm. It's highly probable that dioxins, dioxin-like compounds and other poisons could make their way into the coffee, tea and organic vegetables grown in the region of Cau Dat. Do not forget the study we previously referenced: Study finds large dioxin emissions from Vietnam's waste treatment plants. In this study researchers express concern of "the high chance of dioxin pollution" in the area around incinerators in Vietnam.

The entire approach to household waste disposal in Vietnam demands radical overhaul. The focus must shift from dangerously managing to profitably transforming. Profitable transformation is not difficult to achieve in Vietnam. We have only to look at two things: the composition of household waste and the availability of low-cost labor. The composition of household waste in Vietnam is quite different from that of household waste in developed countries.

The percentage of biodegradable waste within Vietnamese household waste can reach as high as 85% by weight of the total household solid waste stream. Food waste alone is over 50%. What is needed here is the means to store biodegradable household waste on site so as to eliminate the costly step of collecting it and disposing of it each day (The Mesophilic Storage and Reduction of Household Waste).

But if waste is going to be stored on site, it has to be stored without smell, flies, leachate, rodents or any other negative attributes usually associated with waste. Also if waste is going to be stored on site, an enormous reduction in volume during storage must take place. Otherwise the storage vessel would be far too big and costly.

The storage vessel has to be fabricated out of durable materials that last indefinitely and yet at the same time, it has to be relatively inexpensive. The storage vessel must be heavy enough so that it cannot be easily stolen, and it should have little recycle value, making it not worth stealing. Therefore a storage vessel in plastic or metal is not appropriate for Vietnam.

The storage vessel must look good. It must effectively keep out dogs, rats, mice and other such creatures. Its contents must be well aerated. Even though in most cases it's located outdoors, rainwater must not enter. It must be easy to install, operate, maintain and clean out. It should be dimensioned so that it has to be emptied and cleaned out but once each year or two. The residue that remains after clean-out should have considerable value as fertilizer. If the output of farm products is not replaced by the input of transformed biodegradable household waste, sustainability within agriculture can never be achieved.

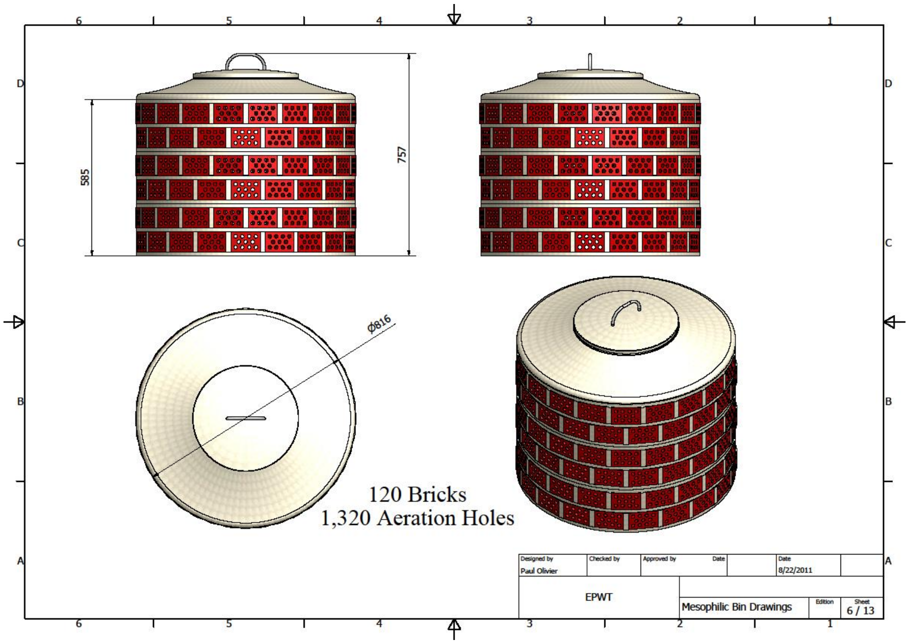
What we are talking about here is mesophilic composting (transformation at level 3). This involves bacteria, actinomycetes, fungi including mold and yeast, protozoa and rotifers, as well as many larger creatures such as worms, snails and larvae. Mesophiles are creatures that grow best at moderate temperatures between 10 and 40 C. We propose that these mesophiles be housed in a bin.

For structural reasons, the body and lids of this composting bin should be circular in shape. The body of the bin can be easily constructed out of brick. The standard construction brick used in Vietnam has a width of 110 mm and a height of 75 mm. These dimensions are OK. But the 6 holes of this brick of a diameter of 25 mm are far too big. Mice and small rats can easily make their way through such large holes. To prevent the entry of rodents, the diameter of the holes cannot be bigger than 14 mm.

So we propose a brick with 11 holes of a diameter of 12 mm, as shown in this drawing (001) and this jpeg (003). Also the standard construction brick is too long. Only one third of its length is needed. The two lids of the bin (003, 004 and 005) are made by means of a radial mold spinning first over sand and then over concrete. This technology is commonly used in Vietnam to make concrete pots for plants. It exists everywhere.

If a bin is situated on dirt, the bin should be mounted over a grouted layer of the same brick with holes vertically oriented. This allows for the entry of red worms and other beneficial creatures. But it blocks out rodents. Rodents cannot gnaw through the bottom, sides or top of this bin. It's totally rodent-proof.

Also no dog, raccoon, skunk or opossum can access it. If bears are a problem, with slight modification, a mesophilic bin can be made totally bear-proof.



The short brick proposed here costs no more than 500 VND or about 2.3 cents US. The extruder tip for extruding six bricks at a time has been made - all quite standard and routine in the brick-making industry in Vietnam.

The holes of the brick are oriented horizontally within the body of the bin. Each brick hole functions as an aeration hole. For more detail on how the bricks are laid out, see drawing 002. Bricks are laid out around a metal jig in a workshop (007 and 008). To see how the sections of the bin are assembled on site, view these jpegs in sequence: 004. 005, 006, 007 and 008.

A mesophilic storage bin can be fabricated for less than 300,000 VND or about $14 US. This cost can be recovered within a period of just a few months of installation, based solely on the fact that so much less household waste has to be collected and disposed of.

Therefore, insofar as possible, each household should be equipped with a mesophilic bin. If a household has no space where a bin could be installed, but if a neighbor does, arrangements could be made for two households to share a bin. In fact many households can share a bin.

Todd Hyman set up an experiment on Hung Vuong Street in Dalat in which over thirty households living in an apartment building shared a single bin. This bin received on average more than 30 kg's of food waste per day. Tens of thousands of BSF larvae inhabited this bin, and these voracious eaters reduced food waste by well over 90% in weight and volume within hours of its introduction into the bin. Mesophilic bins were successfully set up nearby village of Xuan Tho and in many places in Binh Dinh province (The Mesophilic Bin in Binh Dinh).

If it's not possible for a household to own or share a mesophilic bin, then composting can take place indoors in a breathable container such as a plastic or bamboo basket. "If the breakdown of organic waste has taken place as expected, it should take around 3 months for the container to become full" (Takakura Composting Method). Fermentative microorganisms are used in this process.

If it's not possible for a household to master the Takakura composting method, then its biodegradable waste should be put in a special container for collection every two or three days. This biodegradable waste should be brought to a small-scale BSF or thermophilic composting facility. The separate collection of biodegradable household waste is quite common in many European countries.

In a tropical setting, a mesophilic bin is always populated by BSF larvae (provided pesticides are not in use nearby). BSF larvae secrete a pheromone which drives away houseflies and all other filth-bearing flies. No seeding of a bin with larvae is required. Also, if a mesophilic bin is located within at least four meters of soil, it will have a bountiful population of red worms (provided the soil is free of chemical fertilizers and agro-chemicals). Typically no seeding of the bin with red worms is required. If someone wants to harvest larvae from a mesophilic bin, a small gutter can be placed at the base of the bin to trap migrating larvae, as shown here.

A mesophilic storage bin is designed to receive all that biodegrades. Even though bone and shell do not easily biodegrade, they also belong in this bin. Even though biochar does not easily degrade, it, too, can be added to a mesophilic bin. Dry biochar absorbs liquids, and it provides surface area for composting microbes.

Materials that should not be put in a mesophilic bin include glass, metal, plastic, rubber, foam rubber, wax-coated items, textile, stone, sand, rock, rock wool, sponge, brick, porcelain, ceramic and other man-made items. Of course, one should not put into this storage bin biodegradable waste that is recyclable.

A properly maintained bin produces no leachate and has no odor. A bit of dry biochar does marvels in absorbing leachate. A bin can be situated on the concrete or tiled floor of a patio, garage or rooftop. The residue recovered upon clean-out should be screened. Generally the undersize consists of a finished vermicompost. The oversize, consisting mainly of bone, shell and hard cellulosic material, should be shredded and blended back into the vermicompost.

If biodegradable household waste is deposited in a mesophilic bin, the remaining waste is free of messy putrescent waste. Since the remaining fraction does not smell, it can be easily stored on site for a week or two. *This strategy eliminates the daily collection of household waste.* Since the remaining fraction never comes into contact with messy putrescent waste, both the quantity and quality of recyclables recovered by scavengers greatly increases. Only a small fraction of the total household waste stream (less than 5%) does not have recycle value.

When waste is commingled and afterwards attempts are made at separating it (as many incineration companies try to do), more than a third of the recyclables gets contaminated and has little or no recycle value. In order to recycle glass at its highest value, a high level of purity is required. Glass should never get broken and mixed with food waste, textiles and paper. Clear glass is worth about 2.5 times more than mixed glass. Contaminated glass can only be recycled as low-grade aggregate. Paper re-processors will not tolerate contamination with food waste or broken glass. White paper is worth about 5 times more than mixed paper. Aluminum cans that are reprocessed into new cans must possess a high level of purity. Otherwise they must be reprocessed into low-grade aluminum of far less value. Plastics that are not mixed with other plastics generally have a high recycle value. PET plastic, for example, is worth about 4 times more than mixed plastics.

In this concept, biodegradable waste never comes into contact with non-biodegradable waste. This is absolutely critical in any recycling effort. If separation at source does not take place, then it's impossible to separate biodegradable waste from a long list of materials that might contaminate it. As previously explained, if compost is produced from previously commingled biodegradable material, this compost is toxic and dangerous, and should never be used within agriculture (see Source-separated or commingled). Levels of lead, for example, in compost made from commingled waste typically exceed 800 ppm

(Strategies for Separating Contaminants). Making compost from commingled biodegradable household waste should be banned throughout Vietnam. It roughly parallels the danger of making compost from sewage sludge.

To recycle waste at its highest value, Vietnam needs scavengers. If the concept of a scavenger did not exist, we would have to invent it. Scavengers are just about the only people in Vietnam who handle, collect and sort waste correctly at/from its point of origin. These resourceful women go from door to door buying and collecting recyclables. They do not compact waste, crush it or degrade it in any way. They are highly skilled experts who sort and recycle all types of paper, plastic, glass and metal at their highest possible value. They do not require pre-sorting of the non-biodegradable fraction within the household before collecting it. They do not require fancy picking tables to do their job. They sort a lot of their waste during the process of collecting it.

Waste management authorities should confer formal status upon scavengers. They should certify them and grant them full access to non-biodegradable waste at its point of origin.

Unfortunately scavengers in Vietnam are not held in esteem. They are looked down upon and exploited. They end up selling their recyclables to middlemen - middlemen who pay them only a small fraction of the value of their waste - middlemen who are, in stark contrast to poor scavengers, some of the wealthiest people in Vietnam. Here women do most of the work, while men make most of the money - a classic example of gender inequality and exploitation.

Scavengers should be organized into co-operatives in which middlemen play no role. Scavengers should be able sell as high up the value chain as possible. When this happens, scavengers will be incentivized to recycle greater quantities of waste as well as many types of waste that they do not currently recycle. Ideally scavengers should pay nothing to households for the waste they collect, and at least 80% of the resale value of their waste should end up in their pockets.

But someone might object. Ordinances requiring rigorous source-separation at the local level would have to be passed. This would require approval from central government.

No problem here: approval from central government has already been granted. On April 9, 2007, the Vietnamese government issued decree No. 59/2007/ND-CP. This decree stipulates unequivocally that solid waste should be segregated at source, and that source-separated materials should be reused or recycled (see articles 4 and 19). No type of domestic solid waste is exempted or excluded from this mandate. This decree does not merely encourage source-separation. It is not simply the expression of wishful thinking on the part of central government. It actually calls for supervision, monitoring and implementation (see article 28).

Since most source-separation takes place in the kitchen, and since it is predominantly women who cook, the task of source-separating household waste mainly falls on the shoulders of women. Some

Vietnamese men claim that the Vietnamese woman is too dumb to source-separate household waste correctly. Others argue that source-separation would be too time-consuming for her.

But the term "source-separation" is a bit confusing. Household waste does not have to be separated within the kitchen. All that is required is that, as it is generated, the biodegradable fraction must not be mixed with the non-biodegradable fraction. Not mixing is not the same as separating, and not mixing is a lot easier than separating.

Typically the Vietnamese woman has learned how to prepare a large variety of dishes to serve to her family. This requires considerable intelligence and skill. Therefore she can be easily taught how to do one of the simplest of tasks imaginable. If given two containers within the kitchen, she can be taught to put biodegradable material into one container and non-biodegradable material into the other. For example, she can be taught to put a banana peeling in the container for biodegradables, and a plastic bottle in the container for non-biodegradables. It's totally ludicrous for someone to argue that Vietnamese women are so dumb that they cannot distinguish a banana peeling from a plastic bottle in terms of biodegradability.

Also the householder will not lose time, not even a fraction of a second, as she puts a banana peeling in its appropriate container or a plastic bottle in its appropriate container. No more than two containers within the kitchen are required. So her choice is dead simple. Items go in either one container or the other.

Every two or three days she must deposit the contents of the biodegradable container into a mesophilic bin. Once again, she is not so dumb that she will get confused and mindlessly deposit the non-biodegradable fraction into her mesophilic bin. To deposit the biodegradable fraction in a mesophilic bin will take her on average no more than about two or three minutes. This is not a lot of time relative to the total amount of time she spends in a kitchen over a period of a few days. The labor involved here is negligible – just about at zero.

Once every two weeks, a scavenger (certified by the city) could come along and collect the non-biodegradable fraction. At the same time the scavenger could inspect the contents of the mesophilic bin. If the scavenger finds misplaced material in a mesophilic bin, the householder should pay a fine per item of misplaced material. Likewise, if the scavenger finds misplaced material in her non-biodegradable container, the householder should also pay a fine.

But if she does everything correctly, the householder should pay nothing for the processing and disposal of her waste. If she does everything correctly throughout an entire year, she should be given a certificate of excellence in waste transformation along with a meaningful sum of money. She will surely take great pride in managing waste in a responsible manner when properly incentivized.

Any claim to the effect that the Vietnamese woman is incapable of handling waste properly or does not have time to handle waste properly is indefensible. Decree 59/2007 makes a lot of sense and should be strictly enforced throughout Vietnam without exception or excuse. Women who cook and women who scavenge can recycle up to 95% of the total household waste stream at the highest possible value. Vietnamese men, especially those in charge of waste management, should not stand in their way or interfere, as these women carry out this most important task.

The small amount of household waste that these women cannot valorize can be shredded to a grain size of about 12 mm. Shredding is essential in liberating organics from inorganics. After shredding, the waste is too small to be hand-sorted.

So we recommend that it be subjected to one or more dense medium separations at densities below 1.6 using fine sand in suspension. What sinks at 1.6 is an inorganic fraction that can be used as a low-grade aggregate for highway construction. If the 1.6 sinks contain a significant amount of metals, they can be subjected to further dense medium separations at higher densities using ferrosilicon in suspension.

The material of a density between 1.00 and 1.25 contains very little chlorinated plastics. This fraction can be used as a fuel in cement kilns without incurring a high cost in the scrubbing of flue gas. The material of a density between 1.25 and 1.60 is high in chlorinated plastics. This fraction can be incorporated into concrete as a strengthener or binder (Use of Post-Consumer Plastic Wastes in Concrete).

For more detail on this final step in the processing of household waste, see The Processing and Recycling of Automobile and Industrial Shredder Residue. A single dense medium separation facility, as designed by Paul Olivier, can process as much as 80 tons per hour of waste with an accuracy to within a few points to the third decimal place in terms of specific gravity. If this 80 tons represents 5% of the total household waste stream, this equates to the processing of 1,600 tons of waste per hour or well over 30,000 tons per day. No city in Vietnam produces so much household waste.

So we see that through the combined power of women who cook and women who scavenge just about all of Vietnam's household waste can be transformed and recycled. For more in this regard, see Empowering the Poor through the Recycling of Household Waste. Soon we will add the excreta of fish to this treasure trove of waste.

THE ECONOMICS OF A SMALL PIG BREEDING CENTER

We explained previously that the lack of economic opportunity in rural areas forces young people to abandon their villages and move to big cities in search of jobs. However, with minimal investment in rural areas, it becomes possible to reverse this trend. Let us look, for example, at the economics of a small pig breeding center.

In this model, 20 farmers would each be supplied with five weaned piglets per month. If piglets are weaned at 30 days, a sow can produce 2.4 litters per year. Each litter on average would consist of about 10 piglets. To supply 100 weaned piglets each month, the breeding center would need approximately 50 sows and three boars. If the breeding center would sell 100 weaned piglets per month at one million VND ($47.62) per piglet, the total monthly revenue of the breeding center would be 100 million VND ($4,762). The total yearly revenue would be 1.2 billion VND ($57,300).

All of the feed needed by the breeding center would be gathered/grown and fermented by the breeding center. With the cost of commercial feed, chemical fertilizers and pharmaceuticals all at zero, the profit margin for the pig breeding center should situate at about 70%. This would give a monthly profit of 70 million VND ($3,333) and a yearly profit of 840 million VND ($40,000).

Each farmer would need three pig pens of ten square meters, each pen housing five pigs (as depicted in the previous pig pen drawings). Each farmer would sell five pigs per month at an average weight per pig of about 80 kg. Each farmer would bring 400 kg of pork to market each month and would receive at least 60,000 VND ($2.86) per kg for this specialty pork. The monthly revenue per farmer would be 24 million VND ($1,140). The yearly revenue per farmer would be 288 million VND ($13,700).

All of the feed needed by the farmer would be gathered/grown and fermented by the farmer. With the cost of commercial feed, chemical fertilizers and pharmaceuticals all at zero, the monthly profit margin should situate at about 70%. This would give a monthly profit for each farmer of 16.8 million VND ($800) and a yearly profit of 201.6 million VND ($9,600) – a large sum of money for a small Vietnamese farmer. Within the first three months after all 15 pigs are in place, the cost of building pig pens could be fully recovered. Even if the level of profitability were only a third of what is stated here, young people would no longer have to leave family farms and head for large cities in search of low-paying jobs.

The pig breeding center would also assemble and market the 100 pigs produced each month by the 20 farmers. If it would receive 10,000 VND ($0.48) per kg for this service, it would have an additional monthly profit of 80 million VND ($3,800) and an additional yearly profit of 960 million VND ($45,700). The total monthly profit of the pig breeding center therefore would be (70 million VND + 80 million VND) 150 million ($7,140), and the total yearly profit would be 1.8 billion VND ($85,700).

The cost of setting up a pig breeding center, the cost of supplying each farmer with three pig pens, the cost of supplying each farmer with an initial 15 piglets, the cost of supplying each farmer with a gasifier - all total up to less than 735 million VND ($35,000). This cost is small relative to a combined profit of over 556 million VND ($26,500) made each month by the pig breeding center and the 20 farmers when all is fully operational.

None of the above figures include profit on the sale of larvae, red worms and vermicompost. The profit from the sale of these three items should cover a significant portion of the cost of raising sows or growing out piglets. Ideally the pig breeding center would be owned by the 20 farmers as a part of a co-operative.

A similar logic can be applied to the raising of fish in Vietnam.

A CLUSTER OF FIFTY SMALL-SCALE FISH FARMERS

The large-scale factory farming of fish is a dirty business. Stocking densities are high. Mortality is high. Fish are stressed, and they suffer every bit as much as pigs and chickens raised on factory farms (The Case Against Eating Fish). Their immune systems are compromised. Bacterial diseases such as columnaris and enteric septicemia are commonplace (Joint project aims to combat enteric septicemia in basa catfish and First identification of Flavobacterium columnare infection in farmed freshwater striped catfish Pangasianodon hypophthalmus). Large quantities of antibiotics and growth-promoting drugs are used. Harmful compounds get released from fish ponds into aquatic environments. Pharmaceuticals from fish ponds contaminate groundwater, lakes, rivers and oceans (The processes affecting oxytetracycline contamination of groundwater).

The use of unapproved antibiotics in aquaculture in Asian countries such as China and Vietnam "raises significant public health concerns"(Import Alert 16-131). In China and Vietnam raw effluent from disease-ridden conventional pig pens is routed at times to tilapia ponds as feed (Today's Seafood Special: Pig Manure, Antibiotics, and Diarrhea Bugs).

One sees in Vietnam the frequent exchange of catfish pond water, sometimes as often as twice a day when harvest time is near. Water from one of the most polluted waterways in the world (the Mekong) enters the pond, and an abundance of nutrients and antibiotic resistant pathogens are discharged back into the waterway (Dirty Water, Dangerous Fish and Water pollution by Pangasius production in the Mekong Delta, Vietnam: causes and options for control and Spatial and temporal variability of surface water pollution in the Mekong Delta, Vietnam). "While most U.S. seafood is imported, no more than 2 percent is inspected" (Tainted Seafood Reaching U.S., Food Safety Experts Say).

Just a few years ago catfish farms in Vietnam were small. After much consolidation, small farms account today for less than ten percent of catfish farms in Vietnam. A return to small-scale fish farming would solve a lot of problems. But this alone is not enough.

We need small-scale fish farmers who are in total control of water quality – in total control of all that comes in and out of their ponds or tanks. We need small-scale fish farmers who do not employ industrial fish or human food as feed. We need small-scale fish farmers who do not discharge nutrient-rich waste water into groundwater or waterways, but instead return every bit of it to agriculture.

With aquaponics a tight interdependency between fish and plant is created. Plants draw nutrients from transformed fish excreta, and fish tank or pond water is continually cleansed. At first glance this sounds too complicated and too expensive for small-scale farmers to take on. But if we look closely at several aquaponic models designed specifically for poor farmers, aquaponics could become the dominant form of fish farming in Vietnam.

In an exciting paper entitled Distributed aquaponics in urban and peri-urban environments, Jonas Eichhorst writes about a close-knit cluster of 30 to 50 small-scale aquaponic farmers. These small farmers – all of whom are women – do not have to master the production of seedlings and fingerlings. These more complicated tasks are handled by a plant nursery/fish hatchery center. The small farmer has only to grow out fish and vegetables. Catfish and tilapia grow well in aquaponic systems.

When set up properly as Eichhorst proposes, the aquaponic farmer needs no more than 30 square meters in plants and about 6 cubic meters of pond water to generate revenue of more than $500 US per month. (Note that by coincidence, this allocation of 30 square meters for growing plants is exactly the same amount of space mentioned in the previous section for the grow-out of pigs.) The stocking density of fish raised in an aquaponic system (about 25 kg of fish per cubic meter of water) is generally higher than in conventional open ponds.

The aquaponic farmer might devote no more than an hour or two each day in managing such a small-scale operation. This leaves her with ample time to manage household tasks and at least one other farming system. Her productivity in plants can be up to 10 times higher than that of plants in soil-based agriculture. Eichhorst writes of an annual capacity of roughly 1.5 tons for fast-growing crops like lettuces in a space of only 30 square meters.

The aquaponic center provides equipment free-of-charge to each farmer within the cluster. It educates, trains and advises each farmer. It bundles fish and vegetables, and brings them to the most lucrative markets. Since chemical fertilizers, pesticides and antibiotics are never used, products can fetch prices close or equal to those paid for organic food. With aquaponics the loop between fish and plants is closed.

But fish need feed - feed that must come from outside the system. "One of the major cost components for aquaculture in general and the biggest external input into aquaponics systems in value and quantity is fish feed." The aquaponic farmer therefore should be in a position to produce her own feed.

Eichhorst turns to the larvae of the black soldier fly as a "highly valuable source of protein" for an aquaponic system. He explains that the residue of BSF larvae can be further processed into a "great soil conditioner (vermicompost) through the usage of earthworms (typically red worms)." He further explains that the substrates needed to support a small colony of BSF larvae and red worms might consist, for example, of the fecal matter of pigs, chicken and cows collected off of dry bedding.

Depending on the type of fish being raised, he also sees the need for plant-based feed components such as duckweed. In feeding catfish, for example, for every kilogram of fresh larvae about five kilograms of fresh duckweed are needed. This highlights the importance of collecting human urine to grow duckweed. A bucket toilet serving as a urinal pays for itself very quickly.

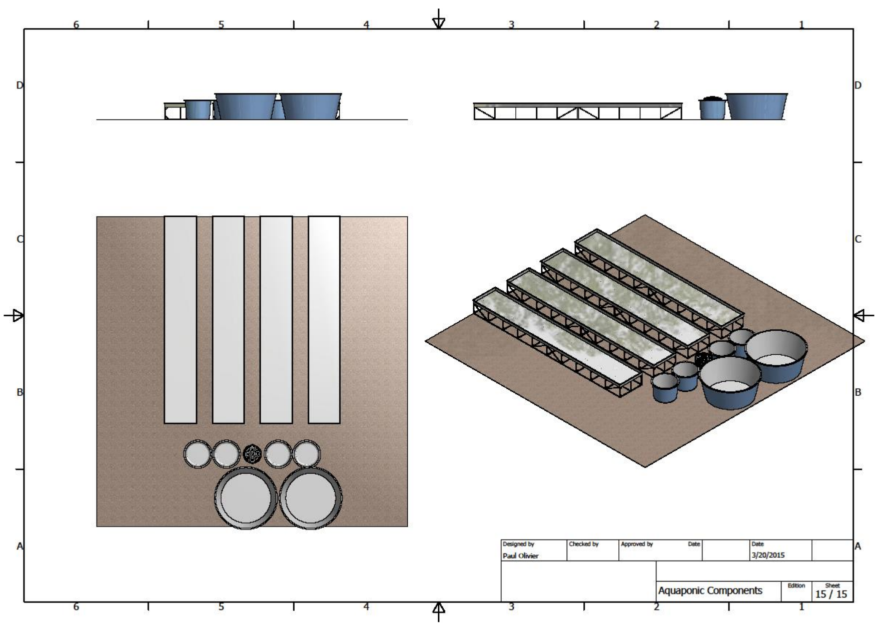
Even coffee pulp can be fed to tilapia, carp and catfish. "The level of coffee pulp used in the experimental diets was close to 33% without negative effects on the growth rate and yields of the fish" (Biological Management of Coffee Pulp).

Vermicompost with biochar can also be used as a medium for seed germination in aquaponic systems. Red worms can even be introduced into aquaponic media beds to break down organic matter. Worms prevent clogging and the formation of anaerobic zones. Surprisingly we discover that media beds can function as vermicomposting beds. Red worms, grown on BSF residue or grown within media beds, can also serve as fish feed.

The aquaponic farmer feeds both larvae and worms to her fish. Fish by-products and vegetable waste from aquaponics can be fermented and fed back to pigs. A similar loop can be set up between chickens and fish. "Sufficient larvae can easily be produced from a few pigs or a small-scale poultry operation."

In aquaponics, rapid nitrification is essential. Nitrifying bacteria operate within biofilm, and surface area is key to biofilm formation. Loose or pelleted biochar has a large surface area, as previously explained, and it's an ideal medium for biofilm formation. Rather than let plant roots dangle in filtered water, one might construct media beds containing coconut coir, vermicompost and biochar.

Media beds create additional surface area for nitrification, they provide structural support to plants, they allow for a greater diversity of plants than purely aqueous systems, and they even support the growth of AM fungi. If media beds contain red worms, vermicompost and biochar, they become hard to distinguish from soil, and like soil, they have never to be replaced.



Eichhorst's aquaponic system is not a conventional aquaponic system. It's a dual loop system. Fish wastewater is processed with such a high degree of efficiency that most of it is returned to fish tanks. A special aerator/clarifier has been designed to process simultaneously the effluent and sludge from fish tanks (drawing 001). When the concentration of nutrients in the fish loop builds up, water from the fish loop is routed to plants. But water from grow bed tables is not returned to fish tanks. This allows the operator to maintain a pH that is ideal for plants and another that is ideal for fish. The main components of an aquaponic system for a small-scale farmer with 40 square meters of grow beds are shown above.

The large-scale factory farming of fish in Vietnam is unsustainable and highly polluting. Eichhorst's aquaponic model offers a powerful alternative, especially when closely linked to other small-scale farming systems such as pigs, chickens or cows. If all of Vietnam's fish were raised in aquaponic systems, the quantity of plants produced would be colossal. Vietnam exports each year more than a million tons of catfish. With the excreta of these fish, Vietnam could grow from 10 to 15 million tons of vegetables per year. Not a gram of chemical fertilizers would be used. And these plants could be raised on about one tenth the space required for growing plants in soil. This in turn would greatly reduce the amount of farmland needed for growing plants. Aquaponics in the hands of urban farmers would reduce even more the need for farmland.

Less farmland and no pastureland are precisely what our planet needs.

A small-scale pig farmer could be at the same time a small-scale aquaponic farmer. For this to happen, she would have to plug into a center in which pig breeding and aquaponics are combined. The larvae and red worms grown on pig feces on a particular small farm would be consumed by fish grown aquaponically on the same farm. All remains local, and the income of a farmer in Vietnam would rise well above $1,000 US dollars per month.

The farmland cogeneration concept we mentioned earlier can be integrated into an aquaponic system. Some plants such as "tomatoes, eggplants and peppers need 6 to 8 hours of sun." But other plants such as "Asian greens, loose-leaf lettuces, mints, basil, parsley and other herbs flourish in part shade and as little as 3 hours of sun" (Urban Gardening Tips). A fair amount of electricity can be generated over plants requiring little sunlight.

If fish swim outdoors in streams, rivers or oceans, their waste cannot be accessed and directed to the growing of plants for human consumption. Aquaponics solves this problem. Fish are enclosed in tanks or ponds so that their fresh waste can be used to grow plants for human consumption. Most people have no problem understanding this brilliant innovation.

But the idea of enclosing poultry and animals indoors on bedding so that their fresh waste can be exploited is not readily understood, especially by those in organic agriculture. They cling to romantic notions of the pig, chicken or cow roaming freely outdoors on a pleasant, sunny day in springtime. The logic of aquaponics could help clarify this issue.

Just as aquaponics does not allow the fresh waste of a fish to dissipate in a stream or river, but encloses the fish in a tank to fully exploit its waste to grow plants for human consumption- so, too, this Third Way does not allow the fresh waste of an animal or bird to dissipate outdoors in a yard or pasture, but encloses the animal or bird on bedding to fully exploit its waste to grow plants for human consumption. And at the same time, this Third Way produces high quality feed in the form of larvae and red worms. Here the creation of feed does not involve photosynthesis, and farmland is not needed. That same feed can be used to power aquaponic systems.

INTENSIVE AGRICULTURAL SYSTEMS

Aquaponics is not a universal solution to growing plants. Only high-dollar, fast-growing plants should be grown aquaponically. Orchard plants, sugarcane and grains, for example, must be grown in soil.

But when grown in soil, plants can still be grown intensively, as we see in SRI (System of Rice Intensification), SWI (System of Wheat Intensification), SSI (Sustainable Sugarcane Initiative) or SCI (System of Crop Intensification). Inorganic fertilizers and agro-chemicals should never be used in these intensive crop systems. Therefore the transformation of biodegradable waste at the highest possible level is essential.

Dr. Norman Uphoff of Cornell University has been credited with spreading the system of rice intensification around the world. In a compelling and powerful paper called Higher Yields with Fewer External Inputs? The System of Rice Intensification and Potential Contributions to Agricultural Sustainability, he takes a strong position against the use of inorganic fertilizers and other agrochemicals in rice cultivation. He states that by raising rice the SRI way, rice yields can double "without relying on external inputs," and that SRI "reduces the need for irrigation water by about half and diminishes the requirements for capital and seed." The amount of seed used in SRI planting is only one tenth of the amount of seed used in conventional planting.

When rice is raised the conventional way under flooded conditions, it takes 3 to 5 tons of water to produce one kilogram of rice. This is entirely too much water, and in Vietnam and many other countries, much of this water is contaminated with arsenic. Even water from deep wells in the Red River Delta and in the Mekong Delta is often contaminated with arsenic (New source of arsenic threatens groundwater in Vietnam, Stanford research finds). As many as 100 million people in Southern Asia have been exposed to health risks from arsenic in groundwater. "The tainted water, used for drinking, agriculture and industry, has resulted in a variety of serious health risks, including cancer."

The upper limit of arsenic in drinking water by WHO standards in 10 µg/L (note micrograms, not milligrams). Groundwater has become the primary source for drinking and irrigation water in Vietnam. "This is a frightening trend, because this groundwater has arsenic concentrations up to 3050 µg/L, primarily in the +3 and +5 oxidation states, the most readily available oxidation states for bioaccumulation" (Arsenic Contamination in Groundwater in Vietnam). In some cases, the sole source of water for domestic consumption and agricultural production is groundwater. In Vietnam, "rice is currently accumulating extreme amounts of arsenic from groundwater," and when this rice is exported, it is "detrimental to global human health."

"Vietnam's rate of malnourished children is 46%, which is almost double that of the world average and over twice as high as East Asian countries' average." When these malnourished children eat rice, they are, in many instances, being poisoned. Could anything be sadder than this?

When rice is grown the SRI way, it is grown under moist, not flooded conditions. This reduces water consumption, and it assures that rice is grown under aerobic conditions. "In flooded soils, arsenic is readily released and available for plant uptake. By contrast, the mobility of arsenic is significantly restricted in aerated soils" (SRI-Rice to take part in study on the potential of the System of Rice Intensification to reduce arsenic in rice). Under water-logged conditions, anaerobic bacteria work on arsenite to release As for uptake by the rice plant.

It is absolutely essential that the rice plant form a mutualistic association with AM fungi. But any condition that results in oxygen deficiency is detrimental to the development and survival of AM fungi. AM fungi may be totally absent under waterlogged conditions. (Alleviation of Soil Stresses by Arbuscular Mycorrhizal Fungi). When AM fungi form associations with the rice plant, arsenate uptake by the rice plant can be reduced by a factor of 2.4 (Effects of mycorrhizal inoculation of upland rice on uptake kinetics of arsenate and arsenite).

At the same time, it is important that the silicic acid be present in the soil where rice is grown. Some paddy fields can be deficient in silica (The Role of Silicon in Suppressing Rice Diseases). If silicic acid is not present, the protein transporters within the rice plant show a preference for arsenic. "When the soil is rich in silica, the uptake of As is reduced" (Protective Paddy Farming Assortment to Diminute Arsenic Contamination). AM fungi immobilize most of the arsenite proportion in the roots of the rice plant (Arsenite transporters expression in rice (Oryza sativa L.) associated with arbuscular mycorrhizal fungi (AMF) colonization under different levels of arsenite stress).

Rice hull biochar contains over 55% silica. It provides, as we have seen, ideal conditions, for the growth of AM fungi. It also retains moisture and reduces the need for water. So the addition of rice hull biochar to SRI soils could make a significant difference in this incredible way of growing rice.

But if rice is to be grown without inorganic fertilizers and other unsustainable and toxic inputs, as Dr. Uphoff recommends, it's essential that the cultivation of rice be coupled to poultry and animal systems.

Ducks can be raised in rice fields, as previously noted. Ducks eat weeds, insects, snails and other troublesome things found in rice fields. And when outdoors in rice fields, ducks fertilize rice with their waste. But duck waste is not enough to meet the fertilizer requirements of the rice plant. We have to look at the possibility of adding more creatures to the cultivation of rice, such as cows and chickens.

Straw should not be burned in rice fields. This gives rise to black carbon and creates CO_2 and other greenhouse gases. Straw in large amounts should not be left to rot in rice fields. This creates methane and other greenhouse gases.

Instead of burning straw or allowing some of it to decompose into methane, we suggest the farmer ferment a good portion of rice straw while still green. The farmer begins by shredding green rice straw to as small a size as possible. Cell breakage "favors bacterial growth and facilitates adequate packing for air exclusion" (Modifying a Thresher for Ensiling the Green Rice Straw by Shredding). For proper fermentation, the bulk density of the shredded straw should be no less than about 70 kg/m^3. It's not difficult to shred green rice straw.

In less than 15 minutes, the normally blunt knives of an axial flow drum thresher can be exchanged for sharp knives to achieve fine shredding. The farmer does not have to buy a separate shredding machine.

Mark Fulford of Teltane Farm grows rice intensively in Maine in the United States. He threshes rice and shreds green straw using the small threshing machine shown in the picture on the right. Fulford has taught thousands of small farmers in the United States and throughout the world how grow crops intensively. He is a true pioneer in crop intensification and in the de-industrialization of agriculture. He believes that small-scale farming is the future of agriculture, even in the United States.

After shredding green rice straw to a small size, the farmer might ferment it together with molasses, rice bran, rice germ and rice hull biochar. "Molasses acts as a binder and pressing aid, improves palatability and digestibility, and is a readily assimilated nutrient assisting the proliferation of desirable lactic bacteria in silage" (Improving the Nutritive Value of Ensiled Green Rice Straw). Rice bran constitutes about 8% of paddy rice and rice germ about 2%, and both contain important nutrients (By-products of Rice Processing). Inoculants such as lactic acid bacteria and cellulolytic bacteria are quite helpful in this fermentation process. The fungal inoculation of rice straw together with EM fermentation also looks promising (The Effects of Effective Microorganisms (EM) on the Nutritive Values of Fungal-Treated Rice Straw). The chemical treatment of rice straw is not desirable or needed.

Fermented green rice straw can then be fed to cattle, preferably cross-bred cattle in a dual purpose milk-beef system.

Since cows cannot be allowed to roam outdoors in rice fields, we suggest that they be raised in proximity to rice fields indoors on bedding. Their bedding would be composed mainly of shredded dry rice straw with some rice hulls and rice hull biochar. The bedding would be sprayed each day with a probiotic liquid. Cow manure can be collected fresh and fed to larvae and/or red worms.

The main fertilizer for rice fields, in this case, is transformed cattle manure in the form of larval residue or vermicompost. And as cattle waste is transformed by means of larvae and red worms into fertilizer, the farmer ends up with valuable feed for chickens and ducks. Chickens love BSF larvae, as we see in this video. So do ducks, as we see in this video.

Ducks for the most part are outdoors in rice fields and derive most of their sustenance as they scavenge outdoors. So we need additional poultry such as chickens to fully exploit the larvae and red worms produced from fresh cow manure. At the same time, this gives a steady supply of fresh chicken droppings.

Chickens should be raised indoors on bedding. Dry rice straw that has been properly shredded could be the principle component of chicken bedding along with some rice hull biochar. Again, daily spraying with a probiotic liquid is important. As the farmer rakes fresh chicken droppings off bedding, she also rakes with it a certain amount of bedding. Fresh chicken droppings do not have to be isolated from or sieved out of bedding. The fact that some of it is raked up each day along with fresh chicken dropping does not pose a problem.

The farmer would then ferment this mixture of bedding and fresh poultry droppings in a manner similar to that described above for green rice straw. Dry rice straw can be deficient in nutrients for adequate bovine growth. So the presence of fresh poultry manure high in nitrogen brings things into balance. When ducks are not outdoors in rice fields (for example, at certain stages in the growth of rice or when brought indoors at night), they too should be housed on bedding so that their waste can be collected and fermented along with chicken waste.

On the benefits of ensiling chicken droppings with dry rice straw, see Effect of chicken age and preservation methods on chemical composition of chicken litter and intake and growth performance of local cattle fed rice straw-chicken litter. Fresh chicken droppings can even be fermented and fed to pigs. But in this swine study rice straw is not used (Ensiling and preserving chicken manure as animal feed and its evaluation in diets of F1 fattening pigs under village conditions). “After 14 days of ensiling, all E coli and Salmonella bacteria in the silage were destroyed.” Also we see that “level of inclusion of chicken manure silage should be no more than 25 – 50% of the diet for pigs of 20 to 50 kg, and 75 % of the diet for pigs of 50-70 kg.”

In the case of cattle, the farmer might mix fermented green straw (without poultry droppings) and fermented dry straw (with poultry droppings), and feed this mixture to her cows.

So in growing SRI rice, the farmer might also grow cows, chickens and ducks. They represent income to the farmer that might surpass income from the sale of rice. Through rice cultivation, the farmer has an inexpensive means of raising cows, chickens and ducks, and through the raising of cows, chickens and ducks, the farmer has an inexpensive means of growing rice. But to arrive at full sustainability in this combined plant, animal and poultry approach, there's one more step the farmer should take. It involves human waste.

We recommend that duckweed be co-cropped with rice. But duckweed would be grown separately from rice in dedicated ponds. Preferably duckweed would be grown on source-separated human urine. It's absolutely essential in the name of sustainability, that nutrients from humans get incorporated in a clean and sanitary way into the production of rice. Humans eat a lot of rice, and at least some of the nutrients in their waste must return to rice.

Duckweed grown on human urine would be fermented with molasses, rice bran, rice germ, rice hull biochar and perhaps some broken rice - and fed to chickens as an important addition to their diet of larvae and worms. According to Dr. Thomas R. Preston, indigenous local chickens appear to have a greater capacity to eat duckweed than exotic breeds (Observations on scavenging local (indigenous) chickens).

Over 7 million hectares of land in Vietnam are devoted to raising rice. They supply more than 30 million tons of straw annually. If this straw were fermented and fed to cattle in cascading and overlapping effects as described above, and if coffee pulp and perennial peanut were also fermented and exploited in a similar manner, Vietnam could boast of an inventory of well over 35 million head of cattle. This number represents almost 40% of the calf and cattle inventory of the entire United States (Cattle & Beef). To raise this number of cattle, Vietnam would not need a single hectare of pastureland or a single cowboy.

Vietnam could become just as much a powerhouse in beef and milk production as it is in rice and coffee production. It could stop importing, making and using harmful chemical fertilizers. And it could put an end to the drain on its economy of importing beef, powdered milk and live cattle for slaughter (Vietnam to spend nearly $5bn on meat, animal feed material imports in 2015).

As noted previously, Vietnam is the world's second largest producer of rice after Thailand. In 2013 Vietnam exported 6.681 million metric tons of rice of an FOB value of $2.893 billion US dollars (Rice Exports). Yet what Vietnam paid out in the import of animal and poultry feed was greater than what it received from the export of rice. If Vietnam were to stop imitating the folly of industrialized agriculture, and if it were to return to the ancient wisdom it once possessed of growing plants and animals together, poor farmers would be empowered, while traders and middlemen in feed and fertilizer would be marginalized.

Over one million small-scale farmers in Vietnam (about 70% of whom are women) have already adopted the SRI system of growing rice. SRI rice is grown on 185,065 hectares of land in Vietnam (SRI Vietnam). Hopefully in the next five years, all rice in Vietnam will be grown the SRI way, and the cultivation of rice will be supported by animal and poultry systems.

COWBOYS OF THE SEA

Previously we stated that we did not like cowboys very much. They destroy rainforests and grasslands in the name of greed and easy money. They take from the land far more than they give. A lot of the waste deposited by domesticated animals in an outdoors setting is poorly transformed and escapes the food cycle. Fertilization from grazing animals is generally inefficient due to losses of P in runoff as well as losses of N in forms of ammonia, nitrous oxide, nitrogen oxide and nitrate.

Virtually none of the waste deposited by animals outdoors makes its way back to farmland. Soil nutrients that give rise to meat, bone and milk are continuously removed from pastureland and are seldom replaced, except, perhaps, through the problematic input of sewage sludge or chemical fertilizers.

Likewise one could make a similar argument with regard to commercial fishermen. What do they give to the oceans? Nothing. They are the cowboys of the sea. They are takers who deplete and destroy our oceans through the continuous removal of fish for human and non-human consumption. "Global fish stocks are exploited or depleted to such an extent that without urgent measures we may be the last generation to catch food from the oceans" (How the world's oceans could be running out of fish). "Scientists predict that if we continue fishing at the current rate, the planet will run out of seafood by 2048 with catastrophic consequences" (The End of the Line - Where have all the fish gone?). Already "ninety per cent of the big fish in our oceans are gone."

Our oceans are being pillaged. They are totally out of balance (Human-Induced Ecological Imbalances: Effect on Ocean and Life). At least one species of ocean fish is on the verge of extinction each day. Scientists fear "that if the destruction of biodiversity continues at the current rate, a mass extinction event will eventually take place" (The Sixth Extinction).

Take a good look at this modern commercial trawler. It's a monstrous and indiscriminate killing machine. "Modern commercial trawlers are the size of a football field, with huge nets (sometimes miles long) that scoop up everything in their path. They can take in 800,000 pounds of fish in just one netting. Trawlers scrape up ocean bottoms, destroying coral reefs" (The Case Against Eating Fish).

Smaller trawling vessels differ only in the size of their destructiveness in a single catch. Commercial trolling vessels also inflict a lot of damage on our oceans (Trolling). Often small artisanal fishermen, employing other fishing methods, overexploit near-shore fish stocks. In Vietnam cyanide and dynamite are widely used to catch fish (BIODIVERSITY: Overfishing Threatens Vietnam's Marine Life).

Perhaps there is no form of fishing more barbaric than Shark Finning. In most cases, the fins of the shark are removed while the shark is still alive. The shark is then tossed back into the sea and dies. The pain experienced by the shark is comparable to that of a man whose ears, nose, fingers and toes were cut off – and he were dumped into the sea to bleed to death or drown.

Experts estimate that about 38 million sharks are subjected to such barbarity each year (38 Million Sharks Killed for Fins Annually, Experts Estimate). Surely a bowl of soup cannot justify such pain and cruelty. Sharks go back 420 million years in evolutionary history. These magnificent creatures "are apex predators and have extensive implications for marine systems and processes, particularly coral reefs." Several species of shark killed for their fins are on the endangered list. One third of shark species are fast approaching endangered status.

What is happening to sharks today resembles what happened in the 19th Century as European settlers in North American set about slaughtering approximately 50 million bison to near extinction for nothing other than their tongues, hides and bone. Their massive carcasses were left to rot.

Alongside overfishing and abusive fishing techniques, there are many things negatively impacting our oceans: warming and acidification, oil spills (The Federal Government Says Billion of Animals Died from the BP Disaster), the trash vortex, microbeads, microfibers, sewage, toxic chemicals, chemical fertilizers, dead zones, the emergence of new diseases and sicknesses that baffle ocean scientists (Federal government investigating Alaska whale deaths), the invasion of alien species, and so forth. Compiling a comprehensive list on ocean ills and abuses would not be an easy task.

When humans existed in small numbers, it was OK for them to take freely from our oceans. But with more than 7 billion people on our planet (Current World Population), we must seriously reconsider what we are doing. At this point roughly one billion people derive the majority of their protein from the sea, while letting the majority of their waste go to waste. How do humans in such large numbers justify taking nutrients while giving back nothing in return?

Even if we wanted to return nutrients to the sea, how do we accomplish this in an economical, sustainable and efficient manner? On the website of the Ocean Foundation under the section Giving Back to the Ocean, not a single viable strategy is discussed on how to return nutrients to the ocean. Ocean fertilization in a well-defined area is not easy. Ocean currents disperse nutrients, and many fish are migratory.

To promote the growth of phytoplankton, some scientists want to distribute iron over large areas of our oceans. But iron fertilization comes at a significant cost and can only be justified economically if supported by carbon credits. According to the United Nations Intergovernmental Panel on Climate Change, the effects of iron fertilization are probably over-estimated, and the potential adverse effects have not been fully taken into account (Ocean Fertilization).

Sperm whales have been acting as agents of iron fertilization for untold millennia. But their numbers have been significantly reduced through whaling, entanglement in fishing nets, collisions with ships, ingestion of ocean debris, ocean noise and chemical pollution (Sperm Whale). In the United States, the sperm whale is listed as endangered.

Some scientists want to add phosphorous and urea to our oceans as a means to sequester carbon and support fish populations. But since these two chemical fertilizers are not sustainably produced, giving here is done at the expense of taking somewhere else. Nitrogen and phosphorous fertilization can easily lead to algal overgrowth and ecosystem disruption. Allowing soil systems to function properly is a far more effective means of sequestering carbon than ocean fertilization.

Since it's impossible to give back nutrients to the ocean in a meaningful way, the only option that remains is to stop taking commercially from the ocean. While the limited harvesting of ocean fish for private consumption could be tolerated, countries should ban the sale of ocean fish at all levels – export, wholesale and retail.

If humans want to eat fish, let fish be humanely raised on farms. Furthermore, fish feed should not be derived from industrial fish or human food. Instead it should be sustainably produced from waste, such as manure (giving larvae and red worms) and human urine (giving duckweed). At the same time, all fish mortalities, fish by-products and fish excreta should be transformed and returned to agriculture.

Fish raised aquaponically are a lot more than the nutrition they provide. Their excreta comprise excellent fertilizer for plants and eliminate the use of chemical fertilizers. *We insist that giving and taking must be rigorously controlled and balanced across multiple methods of waste transformation and across multiple farming systems*. Is this not how we should define sustainable food production?

With a ban on commercial ocean fishing firmly in place, we need not worry about fishermen losing jobs or about people going hungry. Wherever things are done sustainably, an abundance of jobs are created, and these jobs are created at the local level where waste is produced – right where they belong. Wherever things are done sustainably, five to ten times more food is produced. Just as cowboys should learn to become farmers, fishermen should learn to become farmers.

Creating protected areas within our oceans, calling for moratoriums on fishing in certain areas, forbidding the catch of certain types of fish, trying to regulate net mesh sizes, setting up fishing quotas, trying to put in place bycatch mitigation measures, mandating that sharks be brought to shore before their fins are removed - are all strategies that do not go far enough. Creating protected areas within our oceans is like confining wildlife to zoos and parks. Just as wildlife deserves a home free of humans and their domesticated animals, marine life deserves a home free of humans who trawl, troll, trash, torture, plunder and pollute.

Drawing a clear line between domesticated and wild is just as important with respect to fish as it is with respect to animals. Let wolves and tigers, whales and sharks, have homes undisturbed by humans who parasitize the natural world.

Yes, we humans who take from nature without giving back to nature in equal proportion are nasty parasites. In spite of our rationality, we fail to understand that mutualism should define every aspect of how we should relate to the natural world.

When we speak of humans as parasites, we are not just talking about farmers, cowboys and fishermen who behave unsustainably. We are talking above all else about humans who do the actual eating. We are talking about every human who eats anything grown or harvested unsustainably. We are talking about every human who does not insert his or her waste efficiently into the cycle of food production. We are talking about every human who eats the flesh of anything subjected to cruelty and pain.

Where have all the fish gone? Gone to fishermen everyone. When will they ever learn? Oh, when will they ever learn?

A RICE HULL HOUSE

In this essay we talked about equipping rural households with pig pens, chicken pens, cow pens, fish tanks, grow bed tables, fermentation barrels, biopods, red worm beds, duckweed ponds, mesophilic bins, gasifiers, solar panels and dry toilets. But so far we did not talk about the houses in which rural households might live. We also talked about the usefulness of rice hulls as fuel for gasifiers, as bedding for animals and as absorbents in dry toilets. But we did not discuss how rice hulls could be used in home construction.

Back in 2003, a series of ASTM tests were carried out on rice hulls to determine their suitability as insulation. The test results were amazing. Rice hulls, in their raw and unprocessed state, without the addition of any chemicals, constitute a Class A or Class I insulation material. Conventional cellulose insulation, by contrast, requires the addition of chemicals, sometimes as much as 40% by weight, in order to pass these tests. Some of the chemicals found in cellulose insulation are quite toxic (Cellulose Insulation).

The original studies on rice hulls can be found at 001, 002 and 003. Here is a summary of the test results on raw, untreated rice hulls.

1. A Design Density Test: The initial densities of the two rice hull samples tested were 7.729 and 7.488 lb/ft3. After 24 hours of vibration, these two samples increased to 9.972 and 9.807 lb/ft3 respectively. Both samples passed the design density test.
2. Critical Radiant Flux test: Three samples were tested according to test method ASTM E 970. The average CRF was 0.29 W/cm2, the standard deviation was 0.015, and the coefficient of variation was 0.05. All three samples passed this test.
3. A Smoldering Combustion Test: Three sample were tested according to test method ASTM C 739, Section 14. Sample 1 showed a weight loss of 0.07%, sample 2 showed a weight loss of 0.03%, and sample 3 showed a weight loss of 0.03%. All three sample passed this test.
4. An Odor Emission test: The rice hulls were tested according to test method ASTM C 739, Section 13. Since there is no perceptible odor associated with the rice hulls, they easily passed the odor emission test.
5. A Moisture Vapor Sorption Test: Rice hulls were tested according to test method ASTM C 739, Section 12. The sample showed a gain in weight of only 3.23% and easily passed this test.
6. A Corrosiveness Test: The rice hulls were tested according to test method ASTM C 739, Section 9. At the end of this test, the aluminum, copper and steel showed no holes or perforations. Since rice hulls contain no chemical that could corrode metal, they once again easily passed this test.
7. A Thermal Resistance Test: The rice hulls were tested according to test method ASTM C 518. One sample was tested for 120 hours and indicated an R-value of 3.024/inch. Another was tested for 90.3 hours and showed an R-value of 2.926/inch. Another was tested for 92.0 hours and resulted in an R-value of 2.946/inch. Rice hulls have a thermal resistance as good as cellulose insulation.
8. Resistance to Fungal Growth: The rice hulls were tested according to test method ASTM C 1338. Three samples of rice hulls were inoculated with five specific fungal species and left to incubate over 28 days. Once again the rice hulls easily passed this test.
9. Surface Burning Characteristics: The ASTM E84 Standard Test for Surface Burning Characteristics of Building Materials (ANSI 2.5, NFPA 255, UBC 8-1, UL 723) was conducted by Omega Point Laboratories of Elmendorf, Texas. The results here were rather astounding. US building codes require a Fire Spread Index of 25 or less. The FSI for rice hulls was 10. US building codes require a Smoke Development Index of 450 or less. The SDI for rice hulls was 50.

Unlike fiberglass insulation, rice hulls do not irritate the skin, eyes and respiratory track. Check out these images to see the kind of damage that fiberglass insulation can inflict on the human body (images).

Since rice hulls cost so little and make such excellent insulation, we propose that wall cavities have a minimum depth of 30 centimeters or about one foot. This can be achieved by means of a Larsen truss (drawing 001). The outside of the wall truss can be clad in fiber cement. Fiber cement lasts indefinitely, it contains no asbestos, and water cannot penetrate it. The inside of the wall truss can be clad in ordinary drywall. The attic can be filled with 40 cm's of rice hulls. The attic space above the rice hulls should be equipped with a radiant barrier that reflects just about all radiant energy emanating from the roof.

A rice hull house of an interior space of 58 square meters can be built for about 120 million dong ($5,600 US). The basic construction cost is about 2 million dong/m2 or $8.75 US/ft2. The house shown above contains 5.7 tons of rice hulls. In the following jpegs, we see how it all comes together: 001, 002, 003, 004, 005, 006, 007 and 008. In jpeg 006, rice hulls are indicated in brown.

If ever this house should be demolished, all metal can be recycled, and rice hulls can be gasified. Poor people deserve high-quality, affordable housing.

RADICAL TRANSFORMATION URGENTLY NEEDED WITHIN AGRICULTURE

Our goal throughout this paper is to bring wealth to the rural poor and to entice the urban poor to return to rural life. It's a form of socialism requiring little assistance from government, and a form of capitalism grounded primarily in labor, not capital. It seeks to address the gross injustice so often inflicted upon small famers by raw capitalism and the inequality in income distribution such capitalism inevitably creates.

Imagine the situation of a poor farmer faces when she's driven off her land "by an inability to compete with food sold at international commodity prices," and then finds herself in a situation where she cannot afford to buy that commoditized food. Mark Bittman pleads with us: "Think, please, about the horrible irony of that situation, and of what food justice actually means" (Food's Big-Picture Guy). It's squarely about ending the injustice inflicted on poor farmers by large-scale industrial agriculture, whose only goal at times is the blind and irresponsible accumulation of wealth. "Globalization is intensifying food insecurity throughout the world" (Toward a sustainable agriculture).

Everything within industrial agriculture has to change, as forcefully explained in this paper, Paradigm Shift Urgently Needed in Agriculture. This paper draws attention to "a rising chorus from UN agencies on how food security, poverty, gender inequality and climate change can all be addressed by a *radical transformation* of our agriculture and food systems." This paper is bold and right to the point. *It calls for an end to industrial agriculture.* It presents a powerful and compelling argument in favor of farms that are small and biodiverse.

Why small farmers? Small farms predominate in the world today. Of the 1.6 billion ha of global croplands, 800 m ha are smallholder farms cultivated by 99% of the 2.6 billion farmers; most of the farms are 2 ha or less. Together, smallholder farmers produce 70% of the food consumed, and 70% of these farmers are women. Small farms are known to be 2 to 10 times as productive as large industrial farms, and much more profitable, not just in the developing world, but also in the developed world.

But how do the nations of the world put an end to industrial agriculture? It's hard to imagine that change will come about willingly. Two things stand out that just might force radical transformation: climate change and issues relating to human health.

To prevent average global temperatures from rising no more than two degrees Celsius this century, Christophe McGlade of the Institute for Sustainable Resources concludes that "over 80 percent of current coal, half of gas and one third of oil need to be classified as unburnable" (Where in the World Are the Fossil Fuels That Cannot Be Burned to Restrain Global Warming?). Instead of abandoning current reserves, oil companies in 2013 "spent $670 billion in exploring for new oil and gas resources." Bill McKibben, referring to a study in the journal Nature, phrases the debate in much stronger terms: "we have to leave most carbon underground" (Obama's Catastrophic Climate-Change Denial). Leonardo DiCaprio comes to the same conclusion: "Our planet cannot be saved unless we leave fossil fuels in the ground where they belong" (Leonardo DiCaprio Launches Scathing Attack On 'Corporate Greed' Of Energy Industry – Video).

The United States not only extends drilling rights, but it also subsidizes the fossil fuel industry, especially in not taxing drillers and consumers "enough to account for the damage that burning fossil fuels causes to human health and to the climate" (The High Cost of Dirty Fuels). The I.M.F. projects that governments in 2015 will subsidize fossil fuel energy by some $5.3 trillion US dollars. "China, the largest emitter of greenhouse gases, will be responsible for nearly half of that amount, or $2.3 trillion, and the United States will be the second biggest at $699 billion." If these subsidies were eliminated, the I.M.F. estimates that this would reduce carbon dioxide emissions by 20% a year, and it would reduce premature deaths caused by air pollution by 55%. Each year over 2 million lives would be saved.

James Hansen says that if fossil fuel emissions continue on a business-as-usual course, there is near certainty of sea levels rising from 5 to 9 meters (Ice Melt, Sea Level Rise and Superstorms: Evidence from Paleoclimate Data, Climate Modeling, and Modern Observations that 2°C Global Warming is Highly Dangerous). A rise of two degrees C is already highly dangerous, and there's little doubt that average global temperatures will rise well beyond two degrees Celsius.

"Currently, the world is on pace for as much as 5 degrees C of global warming." Food security will be undermined on an unprecedented scale (Panel's Warning on Climate Risk: Worst Is Yet to Come. Drought, along with rising demand from Asia, has already caused the price of beef to soar in America (Beef Prices Soar To Highest Level Since 1987). "Analysis released Thursday from scientists at NASA, Cornell University, and Columbia University predicts that climate change will cause droughts in the Southwest and Great Plains of the U.S. that exceed any experienced in the last 1,000 years" (U.S. Soon to Face Worst "Megadroughts" in a Millennium, Scientists Predict).

According to Dr. Luu Duc Cuong, Vietnam ranks among the top five countries in the world to be severely impacted by climate change (Integration of Climate Change Considerations into Urban Planning in Viet Nam). If sea levels were to rise just one meter, 39% of the of the Mekong, 20% of Ho Chi Minh City and 10% of the Red River Delta would be inundated. A one-meter rise would displace more than 7 million people in the Mekong delta, a region where half of Vietnam's rice and 60% of its fish and shrimp are produced (VIETNAM: Sea-level rise could "displace millions"). "Most coastal cities are highly vulnerable and have limited adaptive capacity," writes Dr. Cuong.

James Hansen and 16 other top scientists predict a sea level rise of over 3 meters in as little as 50 years from now (Earth's Most Famous Climate Scientist Issues Bombshell Sea Level Warning). A 3-meter rise in sea level would have unimaginable consequences for the people of Vietnam. Dr. Cuong estimates that with a 3-meter rise in sea level, about a third of Vietnam would be under water. If a country is literally drowning, the word "adaption" can no longer be used. A 5- to 9-meter rise would be unimaginably horrific.

To achieve food security in the decades to come, Vietnam must learn how to transform waste, how to shuffle transformed waste between multiple plant and animal systems, and how to make use of farmland in an intensive manner. In other words, Vietnam must learn how to distance itself from almost every aspect of conventional, large-scale agriculture in the West (Conventional agriculture poses immense threat to environment, German study says). With small-scale, sustainable agriculture, not only do we have the best way to grow or raise safer, better and more abundant food, but we also have an excellent way to mitigate and reverse the effects of climate change (Small Scale Farmers Cool the Planet).

A similar conclusion is reached in Iowa's Climate-Change Wisdom: "According to a white paper released last spring by the pioneering Rodale Institute, which studies and promotes organic farming, if management of all current cropland worldwide shifted to a regenerative model similar to that of Versaland and other organic farming sites, more than 40% of annual carbon emissions could potentially be captured."

At the same time, we have to address the issue of the remaining 60% of carbon emissions by advancing solar, wind and geothermal - and by taking some of the energy they produce to make liquid fuels from air and water. Markets alone should not determine what happens here. Governments have to intervene on a massive scale. Making liquids fuels from sunlight, air and water must be accorded top priority (Ten Reasons to Take Direct Air Capture Seriously). The money spent on this should exceed by several orders of magnitude the money spent by the United States and other countries on space exploration. Accessing the suitability of Mars to support life and procuring samples of Martian soil are rather trivial endeavors in the context of an Earth that is dying.

But it just might be more immediate issues relating to human health that brings about radical change. Over 70% of human diseases originate with animals (World Livestock 2013 Changing disease landscapes), and "most of the new diseases that have emerged in humans over recent decades are of animal origin and are related to the human quest for more animal-source food." Radically changing the way animals are raised is an absolute necessity.

Bacteria mutate and become increasingly resistant to antibiotics. India has already reached a point where all classes of antibiotics are useless in combating many common infections. These superbugs in India are likely to spread throughout the world. In the United States, an antibiotic called carbapenem is used as a last resort when all other antibiotics fail. Yet there is a particular bacterium called CRE that is resistant to carbapenem. Carbapenem-resistant bacteria are also found in Vietnam: "Vietnam now ranks second out of 26 countries reporting data of carbapenem-resistant E.coli, after India" (Vietnam's antibiotic resistance rate among the highest in the world).

Some say that colistin is the antibiotic of last resort. But there are E. coli bacteria that are not only resistant to colistin, but are also able to transfer resistance to other strains of bacteria. Colistin-resistant E. coli bacteria have been found "in pork, pigs and people in China" and "over a relatively large part of the south of the country" (E. Coli Bacteria Can Transfer Antibiotic Resistance To Other Bacteria). "And the potential for it now to spread not only in China but around the world — you're looking at the potential for untreatable epidemics." Also see this article posted in Thanh Nien News: 'Invincible' bacteria threatens global epidemic: study. Colistin-resistant bacteria have already been discovered in Denmark (Bacteria Resistant to ALL Drugs Shows up in Denmark).

Can you imagine this? Colistin is commonly used in agriculture in Vietnam (Antibiotic use and resistance in emerging economies: a situation analysis for Viet Nam), as well as in aquaculture (Antibiotic Consumption and Resistance Surveillance. What can we do in Vietnam?). The door is wide open in Vietnam for untreatable epidemics.

In a new report on antimicrobial resistance, we see that "The true cost of antimicrobial resistance will be 300 million premature deaths and up to $100 trillion (£64 trillion) lost to the global economy by 2050" (Antibiotic Resistance Will Kill 300 Million People By 2050). Viruses also mutate and find easy targets in immuno-compromised poultry and animals from which infection spreads to humans.

Gary Chandler writes that prions in sewage sludge are killing humans, wildlife and livestock throughout the world. "At least 45 million people around the world already have Alzheimer's disease and other forms of dementia. Millions of other cases are undiagnosed and misdiagnosed. Doctors have suppressed millions of other diagnoses. It's an outrage." He writes that "Pandora-like prions are out of the box and contaminating homes, communities and entire watersheds—including our food and water supplies."

Herbicides, pesticides and many other agro-chemicals are poisoning air, soil and water. With regard to pesticide poisoning, we see that "The latest estimate by a WHO task group indicates that there may be 1 million serious unintentional poisonings each year and in addition 2 million people hospitalized for suicide attempts with pesticides. This necessarily reflects only a fraction of the real problem. On the basis of a survey of self-reported minor poisoning carried out in the Asian region, it is estimated that there could be as many as 25 million agricultural workers in the developing world suffering an episode of poisoning each year" (Acute pesticide poisoning: a major global health problem). "We need to appeal to all politicians all over the world to ban permanently and without exception all pesticides" (Ruthless power and deleterious politics: from DDT to Roundup).

Then there are poisonings associated with herbicides such as Roundup. Some scientists predict that by 2025 half of all children in the United States will be autistic due to poisoning associated with Roundup. Roundup is also associated with elevated rates ADHD, Alzheimer's, anencephaly, birth defects, brain cancer, breast cancer, celiac disease, imbalances in gut bacteria, chronic kidney disease, colitis, depression, diabetes, heart disease, hypothyroidism, inflammatory bowel disease, liver disease, Lou Gehrig's disease, multiple sclerosis, non-Hodgkin lymphoma, Parkinson's disease, pregnancy problems, obesity, reproductive problems and respiratory problems (Monsanto's Roundup. Enough to Make You Sick, Glyphosate's Suppression of Cytochrome P450 Enzymes and Amino Acid Biosynthesis by the Gut Microbiome: Pathways to Modern Diseases , Glyphosate, pathways to modern diseases II: Celiac sprue and gluten intolerance, Glyphosate, Hard Water and Nephrotoxic Metals: Are They the Culprits Behind the Epidemic of Chronic Kidney Disease of Unknown Etiology in Sri Lanka? and Jeffrey M. Smith: Monsanto, GMO Seeds of Destruction).

There are thousands of other deadly agro-chemicals in use throughout the world. Their use is evil. When the production of food is grounded in the use of poison, agriculture has evolved into something truly sinister and has reached its lowest point ever since humans invented it.

This happened about 10,000 years ago, when people in various parts of the world abandoned a hunter-gatherer life style and began to domesticate plants and animals. The Pulitzer Prize-winning author, Jared Diamond, views the adoption of agriculture as The Worst Mistake in the History of the Human Race. He explains quite convincingly that agriculture brought with it malnutrition, starvation, epidemic diseases, class divisions, tyranny, warfare, gender inequality, less leisure time and many other problems. Toward the end of his essay, he uses the phrase "the evils of farming" and comes to the following conclusion:

Hunter-gatherers practiced the most successful and longest-lasting life style in human history. In contrast, we're still struggling with the mess into which agriculture has tumbled us, and it's unclear whether we can solve it.

History here is irreversible. We cannot go back to a hunter-gatherer life style. But we can take steps to clean up, to a limited extent, the grand mess into which agriculture has tumbled us. We must begin now to adopt totally unconventional ways of raising plants and animals. Radical change is the only way of dealing with the evils of farming, especially those evils greatly amplified in recent times by the green revolution and the factory farming of animals. Tweaking fundamentally flawed agricultural systems, as many funding agencies do, will get us nowhere.

There's a lot of talk about sustainability and radical change within agriculture. But often this talk hovers in the realm of generalities and lacks specificity. Someone might argue that it's hard to speak in specific terms in view of the social, economic, cultural and climactic variables found within each country. One way to get around this problem is to define things in negative terms: what no country should allow or condone within its borders, or in national or international waters. If certain unsustainable practices are banned, there would be a rush to find sustainable alternatives adapted to the needs and conditions of each country. This quest would give rise, no doubt, to many novel waste transformation techniques as well as many co-cropping and co-raising combinations not discussed in this paper.

Therefore we propose a partial list of things that should be banned world-wide:

1. Antibiotics should not be administered to anything destined for human consumption.
2. Likewise no other pharmaceuticals such as growth hormones or leanness drugs should be administered to anything destined for human consumption.
3. Arsenic should not be added to animal or poultry feed.
4. Groundwater with high levels of arsenic should not be used for irrigation.
5. The conventional factory farming of animals, poultry and fish should be forbidden.
6. Animals should not be housed on concrete floors.
7. No one should eat the meat of anything subjected to cruelty and pain.
8. Chemical fertilizers, as well as chemical herbicides, pesticides and fungicides, should never be used in agriculture.
9. Human food such as corn, soya and wheat should not be used as animal, poultry or fish feed.
10. Human food such as corn, cassava and palm oil should not be used in the production of fuels such as ethanol or biodiesel.
11. The sale of ocean fish at any level – export, wholesale and retail - should be forbidden.

12. Waste should not be dumped in oceans.
13. Grasslands and forests should not be destroyed to provide pasture for livestock or to grow grain for livestock.
14. Low-grade agricultural and forestry biomass should not be uselessly burned or discarded.
15. Domesticated animals should not be permitted to roam outdoors.
16. Wild carnivores should not be killed to safeguard domesticated animals.
17. Enteric methane from ruminants should not be allowed to escape into the atmosphere.
18. Methane, ammonia, hydrogen sulfide, nitrous oxide and nitrogen oxide from animal waste should not be allowed to escape into the atmosphere.
19. Ammonium, nitrate and phosphorous should not be allowed to migrate into surface or groundwater.
20. Aquaculture pond water should not be discharged into waterways or allowed to seep into groundwater.
21. Water should not be pumped out of the ground at a rate faster than it is being replenished.
22. Nowhere should the rate of soil degradation exceed the rate of soil renewal.
23. Household waste should not be commingled.
24. Compost should not be made from commingled household waste.
25. The backyard burning of waste should be strictly forbidden.
26. The use of non-biodegradable plastic bags and packaging material should be forbidden.
27. Animal waste, biodegradable household waste or commingled household waste should not be burned, incinerated, pyrolyzed, gasified or biodigested.
28. Combustible gases should not be vented or flared in the production of biochar.
29. Charcoal should not be used for the production of high-grade heat.
30. Waste should not be dumped in landfills, streams, rivers or oceans.
31. Water should not be used to flush human or animal waste.
32. Consequently sewage sludge should not be produced, dumped, used as fertilizer or incinerated.
33. Peat, coal, oil, natural gas, methane and methane hydrate should not be extracted from the earth.
34. Liquid fuels should not be generated from fossil fuels or biomass.
35. Nuclear power should not be used to generate electricity.

Industrialized countries would struggle to comply with most of these mandates. But a developing country such as Vietnam is in an altogether different position.

With 71% of its labor force employed in agriculture, Vietnam possesses a huge rural labor force. Through powerful networks of small farmers, it could fully exploit the wondrous efficiency of many natural cycles of waste transformation that all feedback upon one another in a self-sustaining manner. Through powerful combinations of co-cropping and co-raising, it could utilize every square meter of farmland to its fullest potential, it could stop the senseless destruction of rainforests, and it could eventually undertake their rehabilitation and restoration. Bypassing costly sewage treatment plants and highly polluting septic tanks, as well as inefficient biodigesters, it could transform the urine and feces of 90 million people at their highest possible value without wasting a drop of water. Through powerful networks of women who cook and women who scavenge, it could return biodegradable household waste to agriculture and assure that recyclables are recovered at full value. Through the transformation and recycling of every possible form of biodegradable waste, a lot more jobs would be created and a lot more money would be made at the local level.

No longer dependent on the fragile infrastructure of global trade, Vietnam would become strong, self-reliant and sovereign in all that relates to feed and fertilizer production. Through small-scale gasification, it could fulfill most of its need for high-grade heat at the household, agricultural and semi-industrial levels. Through solar and wind, entire villages and even cities could operate off-grid. Vietnam would no longer have to burn fossil fuels to generate electricity (Pollution from coal-fired power plants kills 4,300 Vietnamese every year: study). Nor would it have to build hydroelectric dams or nuclear power stations. By adopting agricultural practices that respect the soil and route carbon into the soil, Vietnam could play an active role in cooling a warming planet.

Through the adoption of these unconventional farming practices, large international corporations that enslave small farmers through the sale of unsustainable and toxic inputs would be shut out, along with traders peddling cheap subsidized products that devastate local economies. The social upheaval caused by the migration of young people to large cities would be eliminated. Poor people, especially poor women, would be empowered as never before. Food production would increase. Trade figures would improve. Food security, along with national security, would be enhanced. Human health would not be endangered. The environment would not suffer. And neither would pigs, chickens, cows and fish.

Mahatma Gandhi once said, "The greatness of a nation and its moral progress can be judged by the way its animals are treated." Let morality override greed, and let radical transformation begin.

In this paper we talk about transforming biodegradable waste at the highest possible level and about shuffling transformed waste back and forth between multiple plant and animal systems. Even human waste must be a part of endless, regenerative cycles of waste transformation. Since fresh waste cannot be transported long distances, the food derived from it must be locally grown. Food is not a just another commodity to be traded in the global marketplace. When all of the environmental benefits of waste transformation are correctly factored into the production of food, food is a lot more than the nutrition it provides. If waste transformed locally is the best thing we've got in producing food, so too, food produced locally is the best thing we've got in cleaning up waste.

Imagine how much money could be saved if farming were de-industrialized to the point where farmers could make their own feed, fertilizer, fuel and biochar. To do this, farmers must learn how to transform all types of biodegradable waste at the highest possible level. If this were to happen, farmers would not just be producers of food, but they would also become primary disposers of biodegradable waste. Since biodegradable waste cannot be transported long distances, since it must be locally transformed, since the food derived from it must be locally raised or grown, this puts farmers everywhere, especially in and around cities, where a lot of waste is generated. As farmers situate in and around cities, the distinction between urban and rural begins to fade, and people everywhere are reconnected to the natural world. As people comprehend the deep connection that should exist between the food they eat and the waste they generate, as they learn to take nothing from nature without giving back in equal measure, they are well on their way to restoring a balance that was lost thousands of years ago with the invention of agriculture.

Nature says to every inhabitant of planet Earth:

If you want food, give me your waste. Give me your waste in a form that I can use. If you do not correctly return your waste to me, you do not have the right to eat.

EPWT