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LIVESTOCK PRODUCTION SYSTEMS ADAPTING TO THE GLOBAL CRISES IN TROPICAL DEVELOPING COUNTRIES: A REVIEW

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ABSTRACT

Food crisis has caused recently severe problems in many countries of the world due to an increasing human population and worsening economic development, and global climate change has made these problems even more serious. Large-scale animal production systems have been established in tropical developing countries to satisfy the animal protein demands of human nutrition (e.g., industrial chicken and pork, feedlot beef cattle, concentrate feeding of dairy cattle), but have caused unacceptable harm to the environment (e.g., high levels of nitrogen and phosphorus entering rivers, and greenhouse gas emissions). As the human population increases, there is a greater risk of protein malnutrition, as well as the risk of environmental pollution resulting from natural disasters. Consequently, the reorientation of animal production systems has become a pressing and high-priority issue in tropical developing countries. In many parts of the world, there are currently constraints on livestock production; however, promising and sustainable models of animal production exist that are based on the utilization of renewable plant biomass as feed for livestock production, while saving grains for human consumption. In addition, diversification of the animal species farmed aids in mitigating greenhouse gas emissions, while adapting to climate change. Utilization of animal production models based on appropriately sustainable farming systems ensure the better use of locally available feeds, while increasing renewable energy production. The sensible selection of livestock production models for sustainable development in tropical developing countries could be beneficial for many producers and for our planet in term of socio-economics and the environment.

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1 INTRODUCTION

The world is faced with a triple global crisis in terms of food, energy (global resource depletion), and climate change, all of which are interrelated and interactive. Although from last year the oil price has been temporarily reduced due to some technical and political reasons (Bocca, 2015), it will continue their generally upward spiral in the years ahead (Worldwatch Institute, 2015). Large changes will need to be made in the future in order to produce and deliver food to maintain the present world population, let alone to ensure a balanced diet for everyone. Fossil fuel energy is the primary resource being depleted, as more fossil energy has been used than is being discovered across the world, and it appears that the reserves of oil that can be cheaply mined are now at peak production, with half these resources having been combusted. The dependency of industrialized countries on oil to drive agricultural production and the fact that most of these same countries cannot meet their own domestic requirements from local resources has seen the headlong development of alternative fuels, including bioethanol produced from sugar cane and maize mainly in Brazil and the USA, respectively, and biodiesel produced from plant oils. This, in turn, has enormous implications for world food stocks and prices, however, potentially creating major cereal food/feed grain shortages as land is diverted from food production to fuel production. Consequently, it is expected that the availability of cereal grain for livestock will be highly restricted across the globe, suggesting that the forage-fed ruminant will be a major source of animal protein in the future. Herbivores in general are also likely to be used more extensively for food, particularly the rabbit, due to its dual capabilities of high reproduction rates and efficient use of forage resources that are produced locally (Leng, 2008).

Tropical developing countries, which are seen by some as backward in terms of agriculture, may be the most capable of supporting themselves in the future through the maintenance of small-scale farming practices that integrate food and fuel production from renewable energy systems. In these countries, there are also opportunities to develop intensive farming systems based on sustainable livestock production through the better use of locally available feed resources to increase food production and reduce environmental pollution from animal wastes and enteric fermentation. This paper aims to introduce some possible livestock production systems that are better adapted to climate change and the food and energy crisis, presenting alternative solutions that are relevant for the existing resources of the world.

1.1 Hungry people in the world and the food and energy crisis

The United Nations Food and Agriculture Organization estimates that about 805 million people of the 7.3 billion people in the world, or one in nine, were suffering from chronic undernourishment in 2012-2014. Almost all the hungry people, 791 million, live in developing countries, representing 13.5% , or one in eight, of the population of developing counties. There are 11 million people undernourished in developed countries. The first and most important is protein-energy malnutrition (WHES, 2015). It is basically a lack of calories and protein. Food is converted into energy by humans, and the energy contained in food is measured by calories. Protein is necessary for key body functions including provision of essential amino acids and development and maintenance of muscles. Because food production is unable to keep up with the increase in the human population. Consequently, there is a high demand for increased animal production and animal products across the world. Water is the main resource required for agriculture, but this has also been depleted. In the past, fossil groundwater (water created as the world cooled many millions of years ago) has been exploited using cheap fuel; however, most fossil resources are now too deep to be economically mined for irrigation, reducing some of the major areas of crop production. Animal feed mainly comes from crop byproducts, with some competition to human pollution and others, i.e., machines (biofuel).

Optimistic estimates for peak production forecast that a global decline will not begin until 2020 or later, and assume that there will be major investments in alternatives before a crisis occurs, without the need for large changes in the lifestyle of major oil-consuming nations. These models show the price of oil first escalating and then decreasing as other types of fuel and energy sources are used (Wikipedia, 2011). As oil reserves are depleted, it is predicted that prices will rise, as for any other commodity. World population expansion has been promoted by the availability of inexpensive oil, which has supported increased food production by providing inexpensive inputs, including fertilizers, insecticides, herbicides, traction power (lowering the need for labor and reducing the numbers of people in farming), and, in places, irrigation water. However, as oil prices rise in the future there is the potential for major disruptions in food availability (Leng, 2008).

1.2 Greenhouse gas emissions and global warming

Many greenhouse gases (GHGs) occur naturally, such as water vapor, carbon dioxide, methane, nitrous oxide, and ozone, while others, such as hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6), result exclusively from human industrial processes. Human activities also add significantly to the levels of naturally occurring GHGs: carbon dioxide is released into the atmosphere by the burning of solid waste, wood and wood products, and fossil fuels (oil, natural gas, and coal); nitrous oxide emissions occur as a result of various agricultural and industrial processes, and when solid waste or fossil fuels are burned; and methane is emitted when organic waste decomposes, whether in landfills or in connection with livestock farming, i.e., enteric fermentation of livestock and animal wastes, and methane emissions also occur during the production and transport of fossil fuels (Fig.1). As the concentration of GHGs increases, more heat is trapped in the atmosphere and less escapes back into space. This increase in trapped heat changes the climate and alters weather patterns, which may hasten species extinction, influence the length of seasons, cause coastal flooding, and lead to more frequent and severe storms, all of which will have negative effects on human activities, life and the environment, such as agricultural production, outbreaks, and disasters.

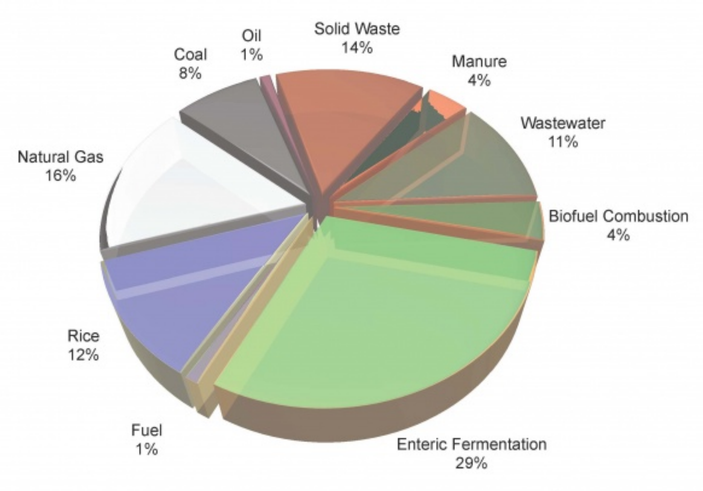

Fig. 1: Global methane emissions from human activities (2006)

M2M, 2006

This is currently a serious problem for countries such as New Zealand, where agricultural methane makes up 32% of the country's emissions. However, it has been predicted that GHG emissions for developing countries will be higher than for developed countries from 2015 (Fig. 2). Therefore, it is of vital importance that developing countries contribute to GHG emissions mitigation as part of a global response to climate change.

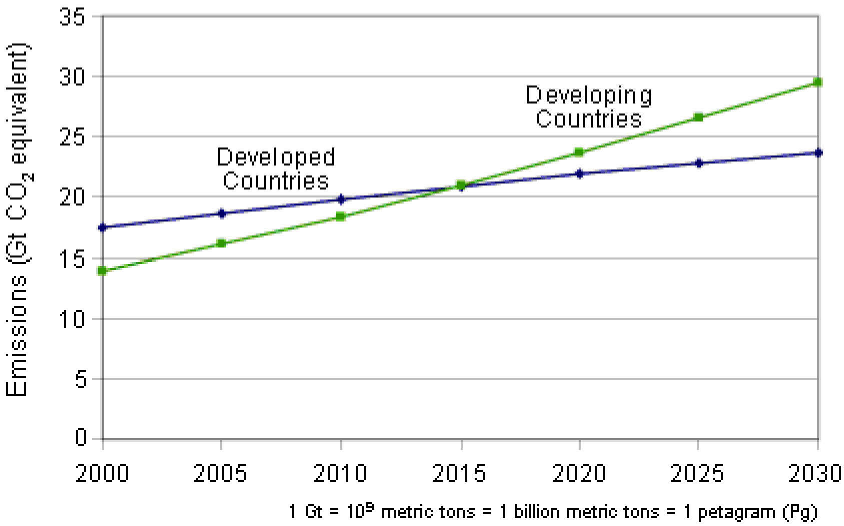

Fig. 2: Total greenhouse emissions for developed and developing countries

2 ANIMAL PRODUCTION AND THE ENVIRONMENT

2.1 Climate change, livestock production, and animal disease

2.1.1 Climate change

The relationship between GHG emissions and climate change and sea level rise has now been accepted and cannot be ignored in any discussion on future agricultural practices. Sea level increases will undoubtedly lead to considerable areas of fertile delta being removed, and weather patterns will certainly change, leading to more intense droughts and/or flooding rains at times. Crop and animal production systems have been adapted to drought, flooding, and saline water effects in a number of areas in Southeast Asia, such as Vietnam and Bangladesh. It has been suggested that we are now entering a stage where grain-based animal production will become increasingly expensive across the globe as there is increased competition for resources for food, feed, and fuel. Consequently, animal production industries based on herbivores will require extensive development to exploit a wide range of waste by products from agriculture or from land that is not dedicated to food or biofuel production (Leng, 2008).

2.1.2 Livestock production

Intensive animal production systems produce high levels of nitrogen and phosphorus wastes, and concentrated discharges of toxic materials, and yet are often located in areas where effective waste management is more difficult. The regional distribution of intensive systems is usually determined not by environmental concerns but rather by ease of access to input and product markets, and relative costs of land and labor. In developing countries, industrial units are often concentrated in peri-urban environments because of infrastructure constraints. According to the Food and Agricultural Organization (FAO), "environmental problems created by industrial production systems derive not from their large scale, nor their production intensity, but rather from their geographical location and concentration," and consequently it recommends the reintegration of crop and livestock activities, which calls for policies that drive industrial and intensive livestock to rural areas with nutrient demand (FAO, 2006). More than one-third of the world's methane emissions is said to be generated by gut bacteria in farm animals such as cows, sheep, and goats. As a GHG, methane is 20 times more powerful than carbon dioxide, which has led to researchers investigating ways to reduce this 900 billion ton annual release of methane (Innovative News, 2009).

Although much evidence has been amassed on the negative impacts of animal agricultural production on environmental integrity, community sustainability, public health, and animal welfare, the global impacts of this sector have remained largely underestimated and underappreciated. In a recent review of the relevant data, Steinfeld *et al*. (2006) calculated the animal agricultural sector's contributions to global GHG emissions and determined them to be so significant that—measured in carbon dioxide equivalents—they surpassed those of the transportation sector.

2.1.3 Animal disease outbreaks

The impact of climate change on the emergence and re-emergence of animal diseases has been confirmed by a majority of the World Organization for Animal Health (OIE) Member Countries and Territories in a worldwide study conducted by the OIE among all of its national delegates (PigProgress, 2009). Climate change is increasing the incidence of viral disease among farm animals, expanding the spread of some microbes that are also a known risk to humans (Physorg, 2009). Vector-borne diseases are especially susceptible to changing environmental conditions due to the impact of temperature, humidity, and demographics on the vectors. However, there is currently only limited evidence that climate change is directly responsible for an increase in the incidence of livestock animal diseases, with bluetongue disease in Europe being one of the exceptions (see below). Climate change eliminates ecological barriers and constraints for pathogen transmission, and the timing of seasonal migration. Because information health systems are limited, changes in disease may have occurred but not yet been detected. As better information systems that are capable of measuring change in disease patterns, vector distribution, and environmental conditions are established, we may be surprised by the number of diseases that are already directly or indirectly affected by climate change. Among livestock diseases, experts agree that there is evidence that climate change explains the recent spread of bluetongue virus observed in Europe since 1998 (Purse et al., 2005). This virus leads to bluetongue, which is a devastating disease affecting ruminants, and is transmitted predominantly through feeding of biting midges of the genus *Culicoides*. In Europe, more than 80,000 outbreaks of bluetongue were reported to the World Animal Health Organisation between 1998 and 2010, and millions of animals died as a result of the disease. Bluetongue was previously restricted to Africa and Asia, but its emergence in Europe is thought to be linked to increased temperatures, which allows the insects that carry the virus to spread to new regions and transmit the virus more effectively.

2.2 Opportunities for developing countries

Response to the challenges posed by global warming and the declining availability of most non-renewable resources will require a paradigm shift in the practice of agriculture and in the role of livestock within the farming system. Farming systems should aim to maximize plant biomass production from locally available diversified resources, processing the biomass on the farm to provide food, feed, and energy, and recycling all waste materials.

The following sections outline an approach whereby the production of food/feed can be combined with the generation of electricity, thus ensuring a supply of both food and energy for families in rural areas. This is achieved through the fractionation of biomass into edible components (for food/feed) and inedible cell wall material. The cell contents and related structures are sources of digestible carbohydrates, oil, and protein that can be used as human food and/or animal feed, while the inedible cell wall material can be converted into a combustible gas by gasification, which is, in turn, used as a source of fuel for internal combustion engines driving electrical generators. An important byproduct of this process is "biochar" (65% carbon: 35% ash), which is both a sink for carbon and a valuable amendment for the typically acidic soils in tropical latitudes. The overall balance of these activities results in a farming system that has a negative carbon footprint.

The production and utilization of biochar leads to integrated farming systems that produce food and fuel without conflict. The principles in such systems are: (1) multi-strata cropping in systems that maximize the capture of solar energy, and provide substrates for the production of food and fuel; (2) a livestock component that facilitates the recycling of high-moisture organic waste through biodigesters to produce fertilizer and cooking gas; (3) gasifiers to produce a combustible gas and biochar; and (4) feed-in tariffs for electricity derived from renewable resources.

It has previously been found that for such systems to be successful there is the need for rural-based support systems for the construction and maintenance of equipment producing renewable energy, and there are advantages of small-scale production systems that facilitate animal traction and the efficient recycling of wastes. Future strategies should include national rebalancing of payments/taxes to compensate rural areas that produce food and energy from renewable resources for consumption in the cities (e.g., through a feed-in tariff for electricity).

2.3 Energy as the stimulus to development – and economic recession

Recession, global warming, and resource depletion (especially fossil fuels) – that is presently facing humanity are closely interrelated. The gaseous emissions from the burning of fossil fuels are the major contributors to global warming; and the apparently inexhaustible supply of fossil fuels facilitated the exponential growth of the world population during the past century and, more recently, the unsustainable indebtedness of developed countries, which led to the economic recession of 2008–09.

The only long-term alternative to fossil fuel (as exosomatic energy, i.e., energy that is not derived from digested food – muscle power) is solar energy, which may be utilized either directly as a source of heat, or indirectly in solar-voltaic panels, as wind, as movements of waves and tides, or in biomass produced by photosynthesis. Solar energy will also have to be relied on to produce food, in what must surely have to be small-farm systems in rural areas, to support the largely urbanized population. The green revolution that dramatically increased food supplies during the last 40 years was a "fossil energy" revolution, as it was energy in the form of oil and natural gas that facilitated the production of fertilizers (especially nitrogen fertilizers), pesticides, and herbicides, and the mechanization and irrigation that permitted multiple cropping.

There are few difficulties in producing food by photosynthesis. However, the redirection of energy from the sun into potential energy to replace that of fossil fuels is more complicated, with many possible methods having been proposed. Rapier (2009) described many of these proposals as Renewable Fuel Pretenders, arguing that their proponents believe they have a solution but that it will never develop into a feasible technology because they "have no experience at scaling up technologies"; in this category, he lists cellulosic ethanol, hydrogen, and diesel oil from algae.

Gasification of biomass as a means of producing a combustible gas has received little attention – perhaps because it is not a new technology. However, in the sections that follow it is demonstrated that this technique holds real prospects of being applicable at the small, dispersed farm level, provided it is developed as a component of a mixed, integrated farming system. The advantages of gasification are that the feedstock is made up of the fibrous parts of plants, which are not viable sources of food or feed; the energy used to drive the process is derived from the combustion of the feedstock; there is minimal input of fossil fuel (mainly for the construction of the gasifier and associated machinery); and the process can be decentralized, as units can be constructed with capacities between 400 and 500 kW.

2.4 Food, feed, and energy from biomass

2.4.1 Food, feed, and energy

Several authors (Brown, 2007 and Falvey, 2008) have challenged the morality of converting food into liquid fuel, in a world where one-third of the population is already malnourished and where there are certain prospects that this proportion will increase as the world population marches on to the 8–9 billion predicted before the mid-point of this century. Second-generation ethanol from cellulosic biomass is also not the answer as, aside from the doubtful economics of the process, the major proposed feedstocks – switchgrass and *Miscanthus* – provide no food component. This conflict can be avoided by using gasification to produce the fuel energy, as the feedstock can be the cellulosic component of the plant, leaving the more digestible protein and carbohydrate components as the source of food/feed. The most useful end products of gasification are electricity and biochar, and so the electrification of most road transport systems is a necessary corollary. Utilization of biochar will be facilitated by locating the gasification process within the farm producing the biomass.

With this process, it is not a question of which activity should have priority, as the source of the biomass should facilitate the production of both food and energy. It is certainly not acceptable, nor is it necessary, to convert potential food sources into fuel, as are the current strategies underlying the production of ethanol (from starch and sugar) and biodiesel (from edible plant oils). Energy from biomass must be derived only from the fibrous residues following extraction of the food/feed component. Many crops lend themselves to fractionation of the food and energy components. In Vietnam, several water plants could be used as human food and animal feeds, e.g., water spinach stems and leaves (Figs. 3 and 4); the water spinach stems are used to make pickles for human consumption, while the leaves with their high protein content are good supplement feeds for rabbits (Thu and Dong, 2011) and other animal species.

Fig. 3: The separation of water spinach to obtain stems for making pickles for human consumption

Thu, 2009

Fig. 4: Water spinach leaves as a good protein supplement for rabbits

Thu, 2011

Water hyacinth (Fig. 5) grows well in canals, ponds and rivers, and in many cases causes environmental problems. This plant has traditionally been underutilized for animal production, but has been studied as a feed for ruminants and rabbits in recent years (Table 1).

Fig. 5: Ater hyacinth obtained from the river and canal in the Mekong delta of Vietnam

Thu, 2009

Table 1: Feed and nutrient intakes (g·animal^{-1}·day^{-1}), and growth performance of rabbits fed different levels of water hyacinth (WH) in a feeding trial

Item	Treatment						± SE/*P*
	WH0	WH20	WH40	WH60	WH80	WH100	
DM intake of WH	-	7.33^{a}	13.0^{b}	18.3^{c}	23.6^{d}	19.7^{e}	0.41/0.001
CP	8.18^{a}	8.42^{ab}	8.51^{b}	8.53^{b}	8.50^{b}	6.81^{c}	0.001/0.001
NDF	32.5^{a}	32.0^{a}	31.4^{ab}	30.8^{ab}	29.8^{b}	22.4^{c}	0.572/0.001
ME, MJ/rabbit/day	0.57^{ab}	0.58^{a}	0.59^{a}	0.61^{a}	0.60^{a}	0.50^{b}	0.024/0.007
DWG, g	18.9^{a}	19.3^{a}	19.6^{a}	19.0^{a}	16.2^{c}	14.0^{c}	0.955/0.001
Feed conversion ratio	3.75^{ab}	3.68^{a}	3.63^{a}	3.76^{ab}	4.37^{b}	4.25^{ab}	0.196/0.009
Econo. return, VND	24,521	24,620	26,279	24,409	16,819	13,265	

WH: water hyacinth; WH0: basal diet; WH20, WH40, WH60, WH80 and WH100: WH replaces para grass at levels of 20, 40, 60, 80, and 100%, respectively, of the amount of para grass consumed in WH0. Means with different letters within the same row are significantly different at the 5% level (Thu and Dong, 2009)

The results in Table 1 show that water hyacinth could be used as a complete feed for the rabbit; however, the optimum level in feed was found to be 40%, with 60% para grass (*Brachiaria mutica*).

2.5 Energy from the fibrous component of biomass

One issue that needs to be addressed is which technology to use to derive energy from fibrous crop residues. Procedures that convert cellulose-rich substrates to ethanol are unlikely to be economically viable (Patzek, 2007) because of the need for mechanical, heat, and chemical energy to convert the cellulose and hemicellulose components into fermentable C6 and C5 sugars. There is also a need for liquid fuels from biomass to be of the "drop-in" variety, so that they are directly miscible with, and hence able to replace, current liquid fuels used for both terrestrial and aerial transport. The most advanced cellulosic ethanol facility appears to be the one owned by the Iogen Company in Canada, which produces ethanol from wheat straw. On the basis of press reports from that company, and data on ethanol fermentation rates of C6 and C5 sugars. Patzek (2007) derived the data presented in Table 2.

Table 2: Comparison of the economics of producing ethanol from maize (established technology) with initial estimates of producing it from wheat straw

	Maize-ethanol	Cellulosic ethanol	Unit
Capital costs (USD)	1.25–1.50	4.30–5.50	Per US gallon
Ethanol yield	98	70–80	Gallons/tonne
Conversion process	Simple	Complex	
Enzyme cost (USD)	0.03	0.30	Per gallon
Alcohol content	14–20%	4%	
Transport and preparation	Low	High	Cost

Source: Patzek, 2007

The steps in the process are as follows: (1) fine milling; (2) addition of water (8 to 9 times the weight of biomass), and application of heat in the presence of sulfuric acid or sodium hydroxide to separate the lignin from the cellulose and hemicelluloses; (3) addition of synthetic enzymes to hydrolyze the cellulose to glucose and the hemicelluloses to pentoses (the latter are not fermented by natural yeasts, so genetically modified yeasts and/or synthetic enzymes have to be used); and (4) the distillation stage (Fig. 6), where more water has to be removed, requiring more energy per unit of ethanol produced. The fermentation of cellulosic ethanol takes much longer than the fermentation of ethanol from maize (120–170 hours compared with 48–72 hours, respectively).

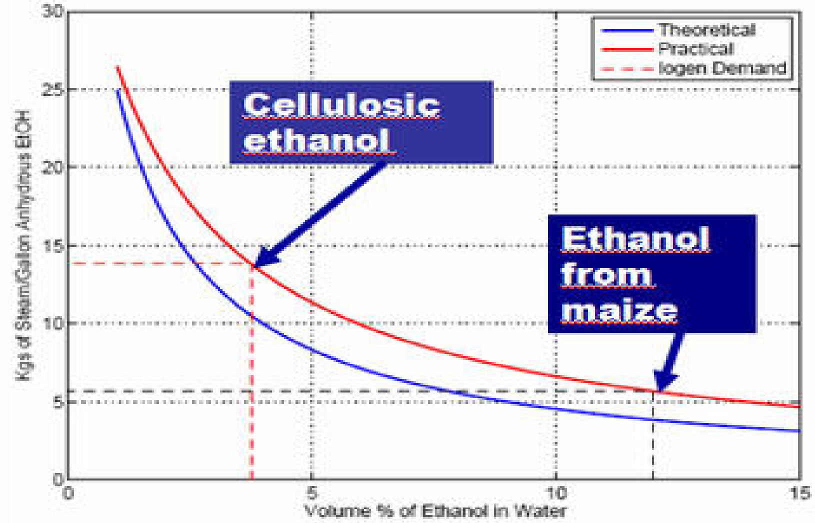

Fig. 6: Fermentation limits and energy required for the distillation of cellulosic ethanol compared with ethanol from maize

Patzek, 2007

The data shown in Table 3 indicate an overall conversion of straw dry matter to ethanol of 0.178; in contrast, the conversion of maize grain dry matter to ethanol is 0.32 (kg ethanol/kg feedstock).

Table 3: Conversion of straw biomass to ethanol

	Biomass, kg	Ethanol, kg
Straw	1	0.178
Cellulose	0.38	0.111
Hemicellulose	0.29	0.067

Assumes enzyme conversion efficiency of 0.76 for cellulose to C6 sugars and 0.90 for hemicellulose to C5 sugars; stoichiometric conversion of sugars to ethanol is 0.51

Source: Badger, 2002

From the limited available information, it is evident that the cellulosic feed stock would need to be procured and transported at a very low price for such a system to be profitable. Consequently, without subsidies, there is little chance that the process would be profitable. Furthermore, other factors must also be taken into account. For example, it has been proposed that the minimum capacity for a viable biomass refinery is of the order of 60,000 tones of dry biomass processed annually (FAO, 2010). The financial and energy cost of procuring low-density biomass, processing it (into pellets or briquettes), and transporting it to a centralized refinery will be considerable; and the social and environmental costs associated with such an operation would be yet another constraint.

Bhattacharya and Kumar (2010) stated that water hyacinth could be used to produce biogas as an energy source. It has also been shown that other plant materials could potentially be used to produce biogas *in vitro* (Trung *et al*., 2009). Figure 7 shows that hydrolyzed water hyacinth, rice straw, and *Brachiaria mutica* grass can produce biogas *in vitro*, with the hydrolyzed water hyacinth and rice straw performing best.

Hydrolyzed water hyacinth has also successfully been used to produce good-quality biogas for cooking or electricity production (Fig. 8) in place of pig manure in a 50-m^3 bio-digester (Table 5).

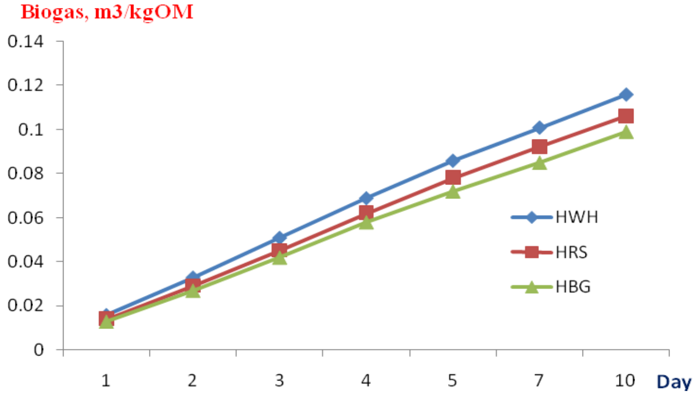

Fig. 7: *In vitro* biogas production of hydrolyzed water hyacinth (HWH), rice straw (HRS), and *Brachiaria mutica* grass (HBG)

Thu, 2011– unpublished data

Table 5: Amount of biogas produced by different levels of hydrolyzed water hyacinth (HWH) replacing pig manure in a 50-m^3 biodigester loaded at a rate of 40-kg fresh pig manure per day

	Treatment					± SE	*P*
	HWH0	HWH 20	HWH40	HWH60	HWH80		
pH	6.81^a	7.08^b	7.14^c	7.15^c	7.17^d	0.006	0.001
Biogas, m^3/day	4.14^a	4.97^b	6.62^c	7.82^d	9.63e	0.067	0.001
Biogas, kgOM	0.079^a	0.121^b	0.133^c	0.100^d	0.076^a	0.001	0.001
CH_4, %	68.2^a	66.0^b	60.8^c	58.4^d	56.8^e	0.125	0.001
CO_2, %	31.6^a	32.5^b	37.8^c	36.6^d	42.3^e	0.187	0.001
CH_4, m^3/day	0.282^a	0.328^b	0.402^c	0.457^d	0.547^e	0.004	0.001
CH_4, m^3/kgOM	0.054^a	0.080^b	0.084^c	0.058^d	0.043^e	0.001	0.001

HWH0, HWH20, HWH40, HWH60, HWH80: hydrolyzed water hyacinth replacing pig manure at levels of 0, 20, 40, 60, and 80%. a, b, c Means with different letters within the same rows are significantly different at the 5% level (Thu, 2011 – unpublished data)

Fig. 8: Producing electricity from the water hyacinth in Vietnam

Thu, 2009

2.6 Diversification of animal species and integrated farming systems

The Global Research Alliance on agricultural GHGs was launched in December 2009, alongside the United Nations Climate Change Conference in Copenhagen. It brings together more than 30 countries who are seeking ways to grow more food without increasing GHG emissions from agriculture. To reach this goal, the Alliance promotes the active exchange of data, people, and research across member countries, of which this paper is an example in the field of livestock production. In addition to addressing the problem of GHG emissions, any animal production system will also need to be adapted to harsh climates, sea level rises, disease outbreaks, increasingly priced grains, and a higher human demand for food. In general, the research literature on GHG mitigation in livestock production can be broadly classified into the following, partly overlapping, categories: improving efficiency in crop or animal production; reducing enteric CH_4 emissions; reducing emissions from manure management; sequestering of soil carbon and plants; and changing human consumption of animal-source food.

In practice, the producers in many tropical developing countries have changed their livestock production processes in response to expensive grain feeds and energy sources, and disease outbreaks. Consequently, more non-ruminant herbivores are being produced for food to reduce GHG emissions and production costs, and to save grains for humans, and there is increasing diversification of animal species to produce animal protein and other products to prevent any further serious outbreaks of disease, including the use of wild animals such as crocodiles, snakes, wild pigs, deers, and guinea fowls.

Fig. 9: Crocodile, horse, and rabbit farming

Thu, 2011

In many parts of the world (e.g., Colombia, Vietnam, India, and Thailand), integrated farming systems that combine crops, animals, and bio-digesters have been successfully developed. These systems have produced more jobs, food, and income, as well as a better environment. They have contributed to sustainable livestock production based on local feed resources, and the increased production of forage as a feed resource for herbivores has enhanced carbon sequestration.

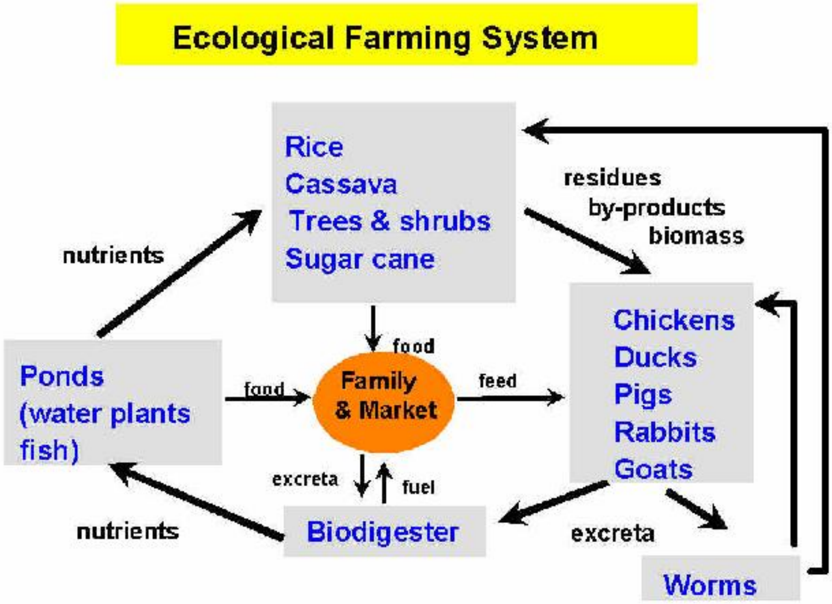

Fig. 10: Livestock production based on an integrated farming system

Du, 2009

A transparent societal and political debate about future options and limitations of sustainable animal production systems requires a clear understanding of the synergies and trade-offs of GHG mitigation options in terms of sustainability issues along the food chain. To gain insight into these synergies and trade-offs, we need to integrate disciplinary models and tools (at interdependent hierarchical levels, across scientific disciplines) with a cause-effect chain approach (i.e., consequential life-cycle sustainability assessment). Combining an integrated sustainability assessment with a cause-effect analysis along the entire food chain will be an innovative approach, particularly in the field of livestock production, and thus will require additional research.

3 CONCLUSIONS

In response to climate change, livestock production strategies should be reoriented to mitigate GHG emissions, reduce the use of grains as feeds, and increase the sustainability of production methods.

Possible technologies to produce both energy and food while mitigating GHG, avoiding animal disease outbreaks, and increasing the income of producers are currently available in tropical developing countries.

The sensible selection of livestock production models for sustainable development could be beneficial for many producers and for our planet in terms of socio-economics and the environment.

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