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AN INTEGRATED ANIMAL-PLANT AGRICULTURE SYSTEM IN THAILAND IN RESPONSE TO CLIMATE CHANGE

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INTRODUCTION

Globally, livestock production is one of the major causes of some of the world's most pressing environmental problems, global warming, land degradation, air and water pollution, and loss of biodiversity. It has been estimated that livestock are responsible for 18 percent of greenhouse gas emissions, a significantly larger proportion of total emissions. However, the livestock sector's potential contribution to solving environmental problems is equally large, and major improvements could be achieved at reasonable cost. The growth of population and incomes worldwide, along with changing food preferences, are stimulating a rapid increase in demand for meat, milk and eggs, while globalization is boosting trade in both inputs and outputs. The livestock sector is undergoing a complex process of technical and geographical change. Production is shifting from the countryside to urban and peri-urban areas, or towards sources of animal feed, whether in feed crop areas or in transport and trade hubs where feed is distributed. There is also a shift in species, with accelerating growth in production of pigs and poultry (mostly in industrial units) and a slow-down in that of cattle, sheep and goats, which are often raised extensively. Today, an estimated 80 percent of growth in the livestock sector comes from industrial production systems. Owing to those shifts, livestock compete directly for scarce land, water and other natural resources.

At the same time, the livestock sector has assumed an often unrecognized role in global warming. The Food and Agriculture Organization of the United Nations (FAO), using a methodology that considered the entire commodity chain, estimated that livestock are responsible for 18 percent of greenhouse gas emissions, a larger share than that of transportation. This accounts for nine percent of anthropogenic carbon dioxide emissions, most due to the expansion of pastures and arable land for feed crops. It generates even bigger shares of emissions of other gases with greater potential to warm the atmosphere: as much as 37 percent of anthropogenic methane, mostly from enteric fermentation by ruminants, and 65 percent of anthropogenic nitrous oxide, mostly from manure.

Livestock production also impacts heavily the world's water supply, accounting for more than 8 percent of global human water use, mainly for the irrigation of feed crops. Evidence suggests it is the largest source of water pollutants, principally animal waste, antibiotics, hormones, chemicals from tanneries, fertilizers, pesticides, and sediments from eroded pastures. While global figures are unavailable, it is estimated that in the USA livestock and feed crop agriculture are responsible for 37 percent of pesticide use, 50 percent of antibiotic use, and a third of the nitrogen and phosphorus loads in freshwater resources. The sector also generates almost two-thirds of anthropogenic ammonia, which contributes significantly to acid rain and acidification of ecosystems.

FAO has stated that the future of the livestock-environment interface will be shaped by how we resolve the balance of two demands: for animal food products on one side and for environmental services on the other. Since the natural resource base is finite, the huge expansion of the livestock sector required to meet expanding demand must be accomplished while substantially reducing its environmental impact.

Intensive animal production systems produce high levels of nitrogen and phosphorus wastes and concentrated discharges of toxic materials. Yet those systems 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 by ease of access to input, product markets, relative costs of land and labour. In developing countries, industrial units are often concentrated in peri-urban environments because of infrastructure constraints. The 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. The possible solution to this dilemma was recommended by the reintegration of crop and livestock activities, which calls for policies that drive industrial and intensive livestock to rural areas with nutrient demand (Steinfield, *et. al*., 2006).

Animal waste as source of pathogens and greenhouse gas emission

Animal production always produces animal waste which is composed of animal manure, urine and in some cases, the wastes water used in the animal raising. Animal manure contains mainly the undigested feed and the body secretion of the digestive tract which contain both an organic portion (protein, carbohydrates, fat and vitamins) and an inorganic portion (N, P, K, Ca, Mg, Na, Cl, S, Fe, Cu, Zn, Mn, Mo, B, Si, Se), together with microbes which naturally reside in the digestive tract of the animals. Microbial content in animal manure is composed of groups of bacteria consisting of pathogenic and non-pathogenic bacteria, archeabacteria, protozoa, parasite and virus. The common pathogenic bacteria found in the animal manure are *Salmonella* spp., *Campylobacter* spp., *Escherichia coli*, *Aeromonas hydrophila*, *Yersinia enterocolitica*, *Vibrio* spp., *Leptospira* spp., and *Listeria* spp. The direct disposal of animal farm wastes without any treatment into the environment is prone to spread pathogens to the local community. However, animal wastes treatment systems either composting, or aerobic digestion significantly reduces population of the pathogenic bacteria and reduces the potential hazard to the public health (Sorbsey, *et. al*., 2001).

The bacterial content in animal manure contains of both aerobic and anaerobic bacteria. Under appropriate conditions, aerobic bacteria will digest the organic part of the manure yielding CO_2which is a greenhouse gas (GHG) and NO_3. But under conventional handling and storage condition, animal manure stimulates the growth of anaerobic bacteria to digest the manure and yield CH_4, NH_4, N_2O, CO_2 and H_2S. Methane (CH_4) and nitrous oxide (N_2O) are more potent GHG than the CO_2 and has global warming power (GWP) of 23 and 296, respectively. Inappropriate handling and treatment of animal manure is, therefore, a potent source of GHG emission for the global warming.

Among the animal farm waste, pig farm waste is the most problematic in handling and treatment due to it slurry characteristics. In general it is easily in an anaerobic condition. In additional, modern pig production employs a high density diet which contains high protein, carbohydrates, vitamins and minerals to promote the high performance of the animal (high growth, lean meat). The modern pig genetics always have a higher sensitivity to stresses, lowering the pig's ability to digest and utilize nutrient in the animal feeds. Modern pig production therefore, potentially produces more waste with higher concentration of both organic and inorganic portion, which not only has the potential to pollute the environment, but also has the potential to produce GHG emission effecting global warming.

Animal wastes handling, treatments and utilization in Thailand

Thailand produces approximately 15 million heads of market pig annually and pig production is among the top ranking animal production of the country. Since pork accounts for 85% of animal meat consumed by the Thai people, pig production continues expanding due to the country's economic and population growth. Commercial pig production in the country employs advanced pig production technology including using high performance breeds of animal (high growth and lean meat), high standards of management practices, and high plane of nutrition to support the optimum performance of the animals. However, the practice had produced a large volume of waste which has polluted natural water resources and is a nuisance to the surrounding communities near the pig farms.

A significant driving force for development of pig farm waste treatment system in Thailand was the promotion of a pig farm standard certification by the Department of Livestock Development (DLD), Ministry of Agriculture and Co-operatives. Certified standard pig farms must process pig waste through treatment systems before the disposal of the pig waste into the environment. In 2003, the Pollution Control Department (PCD), Ministry of Natural Resources, issued regulations for pig farm waste disposal and the discharging of waste water into the environment. PCD required that all pig farm waste to be discharged into natural water resources needed to be treated to the standard shown in Table 1. Violation of these regulations could result in temporary or permanent farm closure. DLD promoted the appropriate waste treatment systems for the pig farms showing how to manage the discharged waste water to meet the requirement standards. Results of these regulations have resulted in most of the existing pig farms in the country having waste treatment system, discharging less pig farm waste into natural water resources, and an increase in the utilization of pig farm waste as fertilizer for crop yield improvement.

Table 1. Standards for waste water discharge from pig farms.

Water Quality Index[1]	Unit	Maximum Standard		
		Standard A[2]	Standard B[3]	Test Methods
1. pH	-	5.5-9.0	5.5-9.0	Electrometric titration pH meter with 0.1 reading resolution
2. BOD	mg/l	60	100	Azide Modification or Membrane Electrode
3. COD	mg/l	300	400	Open Reflux or Closed Reflux Potassium Dichromate Digestion
4. SS	mg/l	150	200	Glass Fiber Filter Disc, dried at 103-105 °C
5. TKN	mg/l	120	200	Kjeldahl method with ammonia detection by colorimetric or ammonia selective electrode

[1]BOD = Biological oxygen demand, COD = Chemical oxygen demand, SS =Suspended solid, and TKN = Total Kjeldahl nitrogen
[2]Standard A: Standard for medium (60-600 LU) to large scale (over 600 LU) pig farm.
[3]Standard B: Standard for small scale (less than 60 LU) pig farm.
Source: Pollution Control Department, Ministry of Natural Resources.

Results of the regulation have indicated that there has been great improvement in pig waste treatment and disposal on the commercial pig farms in the country. Most of the pig farms tried to reduce pig waste disposal into natural water resources by collecting the solid manure and selling it to crop growers as fertilizer or using in their own land. Generally, the collection of dried pig manure was not adequate to meet the demand of crop farmers. Waste water from pig pen cleaning is mostly treated in pond systems or put into various types of anaerobic digesters such as fixed dome, channel digester or covered lagoon for biogas production, and the effluent from the digesters is used in neighboring cropland, or applied on the farmer's own land, or discharging into natural resources. The biogas produced, which is mainly methane (CH_4), is primarily used for on-farm electricity production. A number of large scale pig farms do not collect solid manure but put all the pig manure and water into anaerobic digesters for biogas production before disposalof the treated waste.

The pig farms in Chacheongsao and Nakhon Pathom provinces, where there is limited farm area but ample natural water resources close to the farms, do not usually dispose of waste water onto neighboring cropland. About half of the pig farms in these provinces still discharge treated waste water into the natural water resources. By comparison, Chonburi and Ratchaburi provinces have limited natural water resources and pig production farms are in the middle of large crop farms. Therefore, waste disposal in these provinces is mostly onto cropland with less discharging into the natural water resources.

Crop farmers have learned the benefit of pig farm waste for crop yield improvement, especially for sugarcane in Ratchaburi province, where waste water is pumped and transported to sugarcane plantation for its fertilizer value. Sugarcane farmers generally accept that pig farm waste is the most economical and effective fertilizer for yield improvement. The field information from Ratchaburi province indicates that there will be greater future use of pig farm waste water for sugarcane production. The high percentage of large scale pig farms in Ratchaburi province that dispose pig farm waste onto cropland (70.3%) has greatly reduced discharging into natural water resources (8.1%). There is a strong possibility that the optimal utilization of pig farm waste water for cropland application would allow zero waste discharging of the pig farm into the natural water resources.

Animal wastes as plant nutrient source and organic fertilizer for crop yield improvement

Wastes from modern commercial animal farms which employ high quality concentrated feed have a complete balance of plant nutrients consisting of macro nutrients (N, P and K), micro nutrients (Ca, Mg, Na, Cl and S), and trace minerals (Zn, Mn, Fe, Cu, Mo, B, Ni). Mineral content in animal manure and sludge of biogas digester are shown in Table 2. There is a variation of mineral content in pig manure among the pig farms which is related to a number of factors such as concentration of minerals in the feed, feeding practices, breed of the animals etc.

However, there is less variation of the mineral contents among the manure of pig at different stages in the same farm Table 3. In addition, animal manure also contains microorganisms which acts as the antagonist to plant pathogens, and provide a natural protection to plants. Heydari and Pessarakli (2010) demonstrated that microbial content in animal manure exhibit antagonism against fungal pathogens.

Meanwhile, Zmona-Nahum, *et al*. (2008) demonstrated that some chemical properties of compost extracts from animal manure have inhibitory effects on the germination of *Sclerotium rolfsii*, a significant fungus pathogen commonly causing serious loss and damage to agricultural products. Moreover, microbial content in animal manure produces some plant hormones and plant growth regulators that enhance plant growth and productivity.

Sasaki *et al*. (1990) have reported that *Rhodobacter sphaeroides*, a common non-pathogenic bacteria found in pig manure especially found in anaerobic fermentation of the pig manure produces 5-aminolevulinic acid (ALA), a potent plant growth regulator which enhances chlorophyll biosynthesis and increases photosynthetic activity, thereby increasing productivity. Animal manure is therefore a perfect plant nutrient source and organic fertilizer for crop yield improvement and organic crop productions.

Table 2. Mineral content in animal manure (air dry basis).

Animal Manure	Macro and micro minerals (%)								Trace minerals (ppm)		
	N	P	K	Ca	Mg	S	Na	Fe	Cu	Mn	Zn
Pigs	2.69	3.24	1.12	3.85	1.18	0.19	0.27	0.44	611.07	1030.1	975.75
Biogas sludge	2.23	6.84	0.23	11.7	1.09	1.16	0.07	0.63	1001.7	2060.2	2791.1
Hens, layer	2.59	1.96	2.29	8.09	0.74	0.54	0.32	0.31	75.51	591.87	396.54
Beef cattle	1.36	0.51	1.71	1.76	0.5	0.33	0.73	0.45	40.63	375.86	134.62
Dairy cattle	1.27	0.48	1.42	0.98	0.43	0.31	0.23	0.34	29.92	416.1	121.6
Goat	1.03	0.66	0.64	1.49	0.37	0.37	0.13	0.14	24.78	210.88	125.64
Sheep	0.94	0.54	1.07	1.23	0.34	0.19	0.2	0.11	21.01	205.28	103.53

Source: Juttupornpong, *et. al*. (2009)

Table 3. Mineral contents in manure of pigs at different stages (air-dry basis).

Mineral	G-F	Gestation	Lactation
N (%)	3.64	3.27	3.11
P (%)	3.21	4.49	4.99
K (%)	1.57	0.65	0.84
Ca (%)	5.86	8.71	9.45
Mg (%)	1.31	1.9	2.01
Fe (ppm)	2167	2729	2100
Cu (ppm)	626	124	131
Mn (ppm)	570	876	944
Zn (ppm)	708	1443	1490

The Suwanvajokkasikit Animal Research and Development Institute (SARDI), Kasetsart University (KU), Kampaengsaen, Nakhon Pathom studied and developed the utilization of pig farm waste including pig manure, pig manure extract, pig farm waste water and slurry as well as the digestate and effluent of biogas digester as soil and foliar fertilizer for rice, cassava, sugarcane, vegetables, orchards and flowering plants since 2003. Pig manure extract (PME) a liquid fertilizer is produced by steeping dried pig manure in water at a ratio of 1:10 (dried manure: water) for 24 hours, and removing the solids. The liquid fertilizer is applied as a soil fertilizer or drench. The PME may be diluted at a ratio of 1:10 (PME : water) to make liquid fertilizer for foliar application. The digestate and effluent from biogas digester which contain a high proportion of plant nutrients, anaerobic bacteria and plant hormones was also successfully promoted as organic fertilizer for crop yield improvement. The results of these studies show that all kinds of pig farm waste, with an appropriate quantity and technique of application to the crop, is an ideal and effective organic fertilizer for crop yield improvements without any need for chemical fertilizers.

Utilization of animal wastes for crops yield improvement and reduction of GHG emission in Thailand

SARDI, KU had a cooperation agreement with the Bank of Agriculture and Agricultural Co-operatives (BAAC), which is responsible for more than 85% of crop farmers in Thailand. The agreement was to promote and demonstrate the use of pig manure and pig manure extract for rice and cassava yield improvement for BAAC customers in 6 and 23 provinces in Thailand, for 2008 and 2009, respectively. In 2008, the activities were conducted solely in the northeastern part of Thailand where the soil is very sandy, salty, with low fertility, and produced the lowest average rice yield in the country. Results of these activities clearly showed that pig manure and pig manure extract impressively increased plant yields and, at the same time, reduced the plant production costs as shown in Table 4 and Table 5.

Table 4. Average rice yield and the improvement in 2008 by using pig farm waste as fertilizer compared to rice yield of the previous year (in 2007) by using chemical fertilizer.

Province	No. of farmers	Rice yield (kg per rai)		Yield difference per rai	
		2007	2008	± (kg)	± (%)
Surin	7	446.9	666.4	219.6	67.06
Srisakate	5	364.2	462.8	98.6	78.69
Ubolrachatani	7	393.6	428.9	34.7	91.77
Yasothorn	9	368.1	447.4	79.3	82.28
Roi-ed	5	438	654.4	216.4	66.93
Mahasarakam	10	288.4	597.9	309.5	48.24
Total	*43*	*374.2*	*540.8*	*166.6*	*69.19*

Note: 6.25 Rai = 1 hectare

Source: BAAC (2009)

Table 5. Average rice production cost and the improvement in 2008 by using pig farm waste as fertilizer compared to rice production cost of the previous year (in 2007) by using chemical fertilizer.

Province	No. of farmers	Production cost (baht kg^{-1})		Cost different kg^{-1}	
		2007	2008	± (kg)	± (%)
Surin	7	3.01	1.72	-1.29	-42.86
Srisakate	5	3.78	1.92	-1.86	-49.21
Ubolrachatani	7	2.71	2.57	-0.14	-5.17
Yasothorn	9	4.43	2.53	-1.9	-42.89
Roi-ed	5	3.37	2.68	-0.69	-20.47
Mahasarakam	10	4.21	2.35	-1.86	-44.18
Total	43	3.67	2.31	-1.36	-37.06

Note: 6.25 Rai = 1 hectare

Source: BAAC (2009)

Ii the first year, the inexperience of the farmers in the area, together with the lack of confidence in the technology and infrequent application of pig farm wastes in rice production, the utilization of pig farm waste as fertilizer produced an average of 166.6 kg rai^{-1}, which accounts for 69.19% improvement in rice yield, 1.36 Baht kg^{-1} and a 37.06% improvement in rice production cost in the 6 experimental provinces. It is worthy to note that the optimum rice yield obtained by the well-practiced farmers using pig farm waste as fertilizer in the project, ranged from 800-1,000 kg rai^{-1} under poor soil conditions. The results provided better understanding, hope and promising potential to alleviate the poverty of the people in the region. In 2009, the same activities were conducted in more provinces, including those from the northeastern part of Thailand. Results of these activities also demonstrated the consistent characteristics of pig manure, pig manure extract and pig farm waste in improving rice yield and reducing rice production cost (Table 6 and Table 7).

Pig farm waste has also been successfully tested for yield improvement of sugarcane, para-rubber tree, oil palm, strawberry and mushrooms grown by BAAC customers. In 2010, BAAC is planning to promote the use of pig manure and the pig farm waste water for their farming clientele throughout the country (76 provinces). To date, the use of all kinds of pig farm waste as organic fertilizer, is becoming rapidly accepted by crop farmers. Pig farm waste is increasing in demand but short in supply.

SARDI, KU also have a cooperation agreement with the DLD to study and develop pig farm waste treatment and utilization for crop yield improvement, including the dissemination of knowledge to pig farmers. Thus, SARDI (KU)-BAAC-DLD agreed to cooperate together in the promotion and utilization of pig manure, pig manure extract and pig farm waste water for crop yield improvement of other economic crops grown by BAAC customers. The project is targeted to optimize the utilization of pig farm waste for cropland application and to minimize discharging of waste water from pig farms into natural water resources. Activities are planned in every province in Thailand, including Chacheongsao, Chonburi and Nakhon Pathom province, where use of pig farm waste on cropland is still low and a high percentage of pig farm waste is discharged into the natural water resources. Results of these activities are optimistically expected to result in zero waste discharging into natural water resources.

Table 6. Average rice yield and the improvement in 2009 by using pig farm wastes as fertilizer.

Province	No. of Farmers	Rice Yield (kg rai^{-1})		Difference (kg rai^{-1})
		2008	2009	
Srakaew	6	312	406	94
Roi-Ed	11	315	399	84
Mahasarakam	17	393	463	78
Ubolrachatani	28	336	387	51
Amnartchareon	57	339	411	72
Yasothorn	35	359	498	139
Surin	36	393	452	59
Srisaket	14	408	524	116
Songkla	17	693	834	141
Pattalung	33	447	545	98
Chaingrai	51	570	726	156
Chiangmai	24	560	731	171
Total	329	-	-	-
Average	-	433	538	106

However, to date, the efficacy of pig farm wastes for crop yield improvement has been tested and demonstrated mostly under practical field conditions and the practices are still questioned and doubted by technical personnel in the field of plant production. Therefore, it is necessary to have more, in depth, scientific studies on the utilization of pig farm waste as a plant nutrient source for yield improvement of each economic crop grown. Results of these studies should reduce the resistant of the technical personnel, and promote more utilization of pig farm waste by the farmers under practical field conditions.

There is still a concern over the public health hazards of using pig farm waste for crop yield improvement that has delayed the acceptance of pig farm waste as fertilizer. It is also necessary for more in depth studies to demonstrate the safety of pig farm waste, not only for crop farmers, but also for consumers and for public health. Past experiences suggested that using pig farm waste as organic fertilizer has not only produced the crop yield improvement but has also improved the health status of the crops. Crops with organic fertilizer from pig farm waste are commonly healthy and seldom infested by insects and diseases. Farmers have repeatedly reported the minimal or non-use of plant insecticides or chemicals whenever they use pig farm waste as organic fertilizer. Evidence indicates a great potential to produce organic crops with high yield by using pig farm waste as the fertilizer. The more in depth studies on utilization of pig farm wastes for organic crop production would not only improve the organic crop production efficiency and practices, but also promote more utilization of pig farm waste and reduce discharging of the waste water into natural water resources.

Although there were no scientific evaluation of the effects of animal farm waste utilization for crop yield improvement on the GHG emission of the animal wastes, it is presumed that the application of animal farm wastes either as soil drench or foliar fertilizer will promote more aerobic condition of the animal wastes and consequently reduces or prevents the production of CH_4, N_2O which are more potent GHG produced from animal manure. Moreover, the crops yield increment not only resulted in more food produced for human and animals but also greater fixation of atmospheric CO_2 into the plant products which also resulted in the reduction of GHG emission into the atmosphere.

Table 7. Average rice yield and the improvement by using chemical fertilizer in 2008.

Province	No. of Farmers	Production Cost (baht kg^{-1})	
		2008	2009
Srakaew	6	5.81	3.87
Roi-Ed	11	5.98	4.37
Mahasarakam	17	3.91	3.00
Ubolrachatani	28	2.84	2.10
Amnartchareon	57	3.38	2.25
Yasothorn	35	5.13	2.60
Surin	36	4.48	3.43
Srisaket	14	5.67	3.46
Songkla	17	2.61	1.92
Pattalung	33	4.49	2.62
Chaingrai	51	4.16	2.67
Chiangmai	24	3.72	2.01
Total	329		
Average	-	4.06	2.62

SUMMARY

An integrated animal-plant agriculture system developed in Thailand is aimed to utilize animal farm waste as a plant nutrient source and as organic fertilizer for economic crop yield improvement. The tri cooperation among SARDI-Kasetsart University, which contributed technology and knowledge on utilization of animal farm waste as plant nutrient source, BAAC, which is responsible for most of the crop growers in the country, and DLD, which is responsible for animal farm waste treatment and utilization, have successfully promoted a national program of using of animal farm waste for economic crop yield improvement and for a reduction of the plant production costs. The future of the practice is very promising since it is rapidly being accepted by the crop farmer throughout the country and has created the shortage of animal farm waste in many crop growing areas. Utilization of animal farm waste either as a soil drench or foliar fertilizer will promote aerobic conditions and consequently reduce CH_4 and N_2O emission of the animal wastes. Moreover, the crops yield increment not only resulted in more food produced for human and animals but also greater fixation of atmospheric CO_2 into the plant products which also resulted in the reduction of GHG emission into the atmosphere.

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