Environmental Dynamics in Animal Waste Reclamation in the Scaling up of Livestock in Thailand

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Abstract

Thailand has seen a scaling up of pig production in numbers and structure. Nonetheless, in-house separation and agricultural reclamation of pig solid waste are common practice. Waste reclamation is not taking place under small-scale farming and its environmental dynamics cannot be simply understood as a direct projection to larger scales. Scaling up has transformed the environmental significance of waste reclamation, including waste transfer from livestock to agriculture farmers. Waste transfer benefits pig farmers by trade and removal of waste by agriculture and aquaculture farmers and is key to the environmental dynamics of pig production. However, waste reclamation is not clearly defined as a management option in environmental frameworks. Waste management is mainly addressed as in-farm wastewater with limited attention to agro-environmental values of present practices. To recognise present practices in agro-environmental policies this thesis suggests a descriptive strategy focused on the transfer of waste. Such strategy would avoid command-and-control norms, avoid conflicting with an environmental culture centered in biogas technology and support knowledge transfer in agriculture. A focus on waste transfer from animal farms to agriculture [and aquaculture] plots is interpreted as off-site waste management. Off-site waste management calls for the inclusion of geographical variables beyond animal farms. This leads to an *extended area of environmental influence (EAEI).* Resulting environmental dynamics allows an interpretation of *environment* beyond *resource* in classical agricultural geography to a connotation where *environment* is also significant to agriculture and livestock because of the impacts from production. The recognition of reclamation practices and, consequently, of the integral environmental dynamics, and hence the connotation of *environment,* would contribute to connect livestock with agriculture through environmental geography. Intensive livestock is then defined as distribution and not location. Formalisation of reclamation practices entails the acknowledgment of agro-ecological cycles in livestock.

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Abbreviations

BOD: biological oxygen demand

COD: chemical oxygen demand

DLD: Department of Livestock Development

GHG: Green House Gases

LDD: Land Development Department

LU: Livestock Unit. In Thailand 1 LU = 500 Kg., where, sow = 170 kg/head, nursling pig = 12 kg/head, and fattened pig = 60 kg/head. (MNRE, 2005)

LWMEA: Livestock Waste Management in East Asia

MANNER: Manure Nitrogen Evaluation Routine

Nres: Residual Soil Nitrogen

PCD: Pollution Control Department

PES: Payment for Environmental services

pH: effluent’s acidity

SEQ-Survey: Soil Environmental Quality Survey

SS: suspended solids

STRAW: Support For The Treatment And Recycling Of Animal Waste

TKN: Total Kjeldahl Nitrogen

Declaration

The material contained in the thesis has not been previously submitted for a degree in this or any other institution.

Acknowledgment

The best lesson learnt from this research has not been one derived from readings and fieldwork, but from one particular virtue of my Supervisors, Professors Dr Jonathan D. Rigg and Dr Timothy P. Burt; my most sincere gratitude for your patience with me.

1. INTRODUCTION

1.1 Research Rationale

Literature covering the transformation in global agricultural production in the last decades is abundant. Steinfeld et al. (2006) *Livestock's long shadow* explains how animal production has developed with the intensification and industrialisation of animal farming. New methods in animal husbandry, an increase in the scale of operations and a detachment from agriculture have transformed traditional environmental dynamics of animal production. One clear outcome of new animal production scenarios highlighted by Steinfeld et al. (2006) is the environmental impact from nutrient surpluses.

The environmental situation from the scaling up of production exists and challenges farmers and policy makers (Cloutier et al., 2003) in developed and developing countries alike (Martinez et al., 2009). Secondary data presented in this thesis shows that Southeast Asia as a developing region has witnessed a considerable increase and transformation in production over a short period of time. Delgado et al. (2003) assess the nutrient balances in several case studies in selected fast-growing developing countries, including Thailand, and points to nutrient surpluses from large-size pig farms. Moreover, such increase is likely to continue (Hoffmann, 1999; Kristensen et al., 2004; Steinfeld et al., 2006; Tisdell, 1998). However, this transition in production has not been matched in the development of environmental management of animal production (Global Environmental Fund [GEF], 2005; Gerber & Menzi, 2006) and policies over livestock environmental management need further attention.

As a result, modern animal production causes environmental impacts at various levels. Practically, all these levels stem from one common root: waste management. In this regard, pig farming is known to be especially challenging in terms of environmental management because of the large quantities of waste produced, particularly when conditions in pig production in hot and humid countries, as in the case of Thailand (see Udomprasert, 2006), are taken into account, i.e., cooling down the animals and washing their pens produces additional wastewater.

An additional complication in managing pig waste is that characteristics and quantity of waste produced depend on the animals' physiological conditions, e.g., pregnancy, weight, age or type of nutrition, (Aarnink & Verstegen, 2007; Dourmad & Jondreville, 2007) to the point that, according to estimates by Rademacher (2000) cited in Aarnink & Verstegen

(2007), land required for manure application could considerably be reduced under special feeding plans.

Nevertheless, quantifying nutrient loads, budgets and flows is difficult and can be greatly variable if calculations take into account farm dynamics, such as changes in stocks —see for instance the all-in-all-out method in Udomprasert (2006)—, the increase in weight in animals, the proportion of sows to fatteners or even commercial arrangements[1].

In Western countries it is common practice for industrial operations to manage pig waste as slurry, the mix of liquid and solid excreta, and dispose it in agricultural fields (Ferket et al., 2002; Petersen et al., 2007). It is apparent that the disposal or usage of slurry in agricultural fields is the ultimate waste management practice despite various technological solutions available nowadays for the environmental management of waste.

On the other hand, in the case of Thailand (Rattanarajcharkul et al., 2000) and in other countries in Southeast Asia, e.g., Vietnam (Tuan et al., 2006), in line with ecological sanitation paradigms in human waste management, the solid fraction from pig waste is frequently managed separately from wastewater. Solids are removed from the floor before pigs and pig pens are washed and flushed with water. This process greatly prevents mixing solid and liquid wastes, reduces the concentration of nutrients in wastewater and improves its manageability, particularly when farms have low mechanization levels. Solids are then used in agriculture or aquaculture, as reported in Vietnam (Tuan et al., 2006), or in Thailand (Rattanarajcharkul et al., 2000; Gerber & Menzi, 2006; Kiratikarnkul, 2008), and thereby confirming information collected during fieldwork. In fact, agricultural use of pig solid waste in Thailand is common practice as it can be deducted from the survey on pig waste management conducted by the Department of Livestock Development (Department of Livestock Development [DLD], 2000) and released in the year 2000. Although the DLD (2000) survey does not specifically mention the disposal or agricultural use of pig solid waste, this thesis argues that such practices are contingent and often subsidiary to those presented in the survey. Furthermore, the DLD (2000) survey shows that the adoption of different waste management options recorded in the survey depends on the size of the pig farm (measured in the survey in stock units).

For that reason, the structure of production resulting from scaling up processes might determine important patterns in waste management and therefore in the environmental dynamics of pig production. By this means, solid-wastewater separation and agricultural use of solid waste as waste management alternative might play a critical role in the

[1] *For instance, commercial agreements for animal weight at slaughter.*

environmental dynamics of pig production under present production scenarios. However, no policy seems to address this question. This thesis therefore investigates the environmental dynamics resulting from the scaling up of pig production in Thailand by looking at the environmental significance and functioning of in-house solid waste separation and agricultural reclamation of pig solid waste.

This thesis questions if practices on pig solid waste separation and agricultural reclamation can simply be understood as based on traditional use of manure in agriculture. The structure of pig production in terms of farm size, distribution and concentration, the dynamics of present animal and agricultural farming, farms environmental management and policies, in addition to multiple other factors in relation to agricultural geography, such as the detachment of animal production from agriculture, are expected to affect the functioning and significance of waste reclamation practices. This thesis postulates that waste reclamation practices remain widely common, not only at small-scale pig farming but at larger scales of production. However, with the scaling up of production these practices are not taking place under traditional production scenarios and their functioning in the environmental dynamics of pig farming cannot simply be understood as a direct projection from small-scale to larger scales of production. This suggests that, in Thailand, the scaling up of production might have transformed the role and significance of solid-liquid waste separation and agricultural reclamation within the environmental dynamics of pig production.

The transformed environmental significance can be interpreted under an agro-ecological framework as a positive outcome in terms of nutrient balances and the reintegration of animal and agriculture production. However, the practice is not free of environmental risks and, moreover, environmental frameworks seem to overlook, on one hand, the environmental significance of waste reclamation as a pig waste management practice, and, on the other hand, the environmental risks associated with the practice. Therefore, how environmental frameworks address the present structure of production resulted from the scaling up of production might be inconsistent with the continuation of this practice and its environmental significance. Moreover, the analysis of the environmental significance of waste reclamation practices opens a window into what would mean the hypothetical integration of such practices into environmental policies. This might have implications on how agricultural geography is seen nowadays.

1.2 Objectives and Research Questions

The main objective of this thesis is to interpret the functioning and environmental significance of pig solid waste agricultural reclamation in the environmental dynamics resulting from the scaling up of pig production in Thailand. To do so with the intention of informing policies over animal production, this research uses the framework of agro-ecological sustainability by Dalgaar et al. (2003).

This main objective can be dissected into the following sub-objectives:

- To explore how the scaling up of livestock production has transformed waste reclamation practices.
- To explore how these practices function at animal farm waste management level.
- To explore the ramifications of the practices at agro-environmental level.
- To explore the significance of these practices at policy level.

These sub-objectives lead to the following research questions:

- How have animal waste management practices been transformed under the scaling up of animal production in Thailand?
- How do these practices function at the level of animal farm waste management?
- What are the environmental ramifications of these transformations at agro-environmental and agricultural geography level?
- What is the significance of these practices in environmental governance?

1.3 Analytical Framework

From Steinfeld et al. (2006) at a global level, narrowed down to Southeast Asia in Gerber & Menzi (2006) and to the case of Thailand in Delgado et al. (2003), a key issue in the environmental impacts from pig farming is nutrient surpluses. From a theoretical point of view, this thesis analyses the function and significance of agricultural reclamation of animal solid waste as a linking mechanism in the environmental dynamics resulting from the scaling up of animal production in Thailand. This analysis is then projected at policy level and to the realm of agricultural geography. This thesis uses the case of in-house pig solid separation in pig farming and informal practices in pig solid waste reclamation in agriculture in Thailand under the analytical framework of agroecology and scales offered by Dalgaard et al. (2003).

Dalgaard et al. (2003) defines agroecology as *"interactions between plants, animals, humans and the environment within agricultural systems".* Dalgaard et al. (2003) highlights the difference between common working scales in agroecology and scales in policies. In relation to the issue of nutrient surpluses above mentioned, the study of agricultural reclamation of pig solid waste in Thailand is fundamentally related to complexities associated with scales in agroecology and the environmental dynamics resulting from the scaling up of pig production affecting the connection between agriculture and livestock in terms of nutrient balances. When projected at policy level, environmental governance of waste reclamation echoes this complexity contingent to socioeconomic and geographical factors. The Nitrates Directive (Nitrates Directive 91/676/EEC) in the European Union (EU) provides an example of the complexity of matching scales between policy and agroecology. The Directive defines thresholds for manure application in agriculture. However, it is unclear how these thresholds were reached and some countries have claimed that they are inappropriate for their geographical conditions (Schröder & Neeteson, 2008; Department of Environment, Food and Rural Affairs [DEFRA], 2007; 2008).

Pelosi et al. (2010) draws attention to the shortcomings in agroecological systems in a research originated from the domain of biodiversity conservation and agriculture. Differences aside, this present thesis follows the theoretical framework of Pelosi et al. (2010), which claims that there is a pitfall in the lack of a systemic approach with a "*spatial scale mismatch between ecological processes and agricultural management*". In the quest of applying a systemic approach in the implementation of the framework by Dalgaard et al. (2003), this thesis follows Kruseman's et al. (1996) conceptual framework for the agroecological and socioeconomic analysis of land use sustainability. Kruseman et al. (1996) proposes a three-level approach (plot, farm and policy level) which identifies natural and environmental processes at plot and farm level and socio-economic processes at higher hierarchical levels on which, in line with Dalgaard et al. (2003), policies are based.

To reach the policy level, this thesis analyses the significance of animal waste reclamation in the scaling up of production in Thailand by following the structural levels proposed by Kruseman et al. (1996) and the conceptual framework of agroecology and scales by Dalgaard et al. (2003). Linking mechanism among the several levels of the structure under the framework of agroecology is the transfer of nutrients between livestock and agriculture and the potential environmental impacts deriving from such transfer or lack of.

This linking mechanism is also interpreted under two additional perspectives. One is through the observation of "*agroecology as the ecology of food systems*" (Francis et al., 2003) and how this affects the view of agricultural geography as the geography of food suggested in Atkins (1988). The other is through the observation of the economic approach to land availability as factor in the global geographical distribution of pig production (Park et al., 2006) based on the need for land in the environmental management of pig farming. However, in connection to economic and environmental policies, such view is challenged by the Pollution Haven Hypothesis in economy and trade over the transfer of pollution when production moves to locations with less restrictive environmental policies (see Taylor, 2004).

An additional element linking the different levels (plot, farm, policy) building Kruseman's et al. (1996) framework applied to the environmental dynamics of pig production in Thailand relates to political ecology and the environmental views of actors affecting policies —drawn from the concept of "*ecological culture*" in Escobar (1996)—. Finally, the multifunctional view of agriculture beyond food production (Renting et at., 2009) applies to the function that agriculture provides to the environmental management of pig production in Thailand. In this context, waste reclamation in agriculture opens an opportunity for payments for environmental services (Wunder et al., 2008) as an option in cases where a market solution for waste reclamation is not feasible because of particular conditions exerted by agricultural or environmental geography affecting waste reclamation practices in a given area.

1.4 Research Design

This research is fundamentally based on the analysis of available quantitative data on pig production in Thailand and the collection of qualitative data by expert interviews and field work in pig farms and sites related to the agricultural reclamation of pig waste. Therefore, there is a collection of data from primary and secondary sources. First, data from secondary sources includes data from official sources such as the Thai Pollution Control Department (PCD), the Livestock Statistics Year Books and international sources such as statistical livestock production data from the Food and Agriculture Organization of the United Nations (hereafter FAOStat followed by the year data was accessed). Secondary data was also collected from relevant literature including unpublished reports and other non peer-reviewed sources such as papers from national and international organizations and working groups organized under diverse programmes within the field of livestock and environment. Secondary data was used to investigate environmental practices in pig production and the scaling up leading to present production scenarios in Thailand. The analysis of secondary data justifies the use of medium-scale pig farms as the focus of attention for primary data as addressed below.

In terms of primary data, information was collected by visits to field sites and expert interviews. Qualitative field data was collected by a non-purposive sampling in the form of visits to nine field sites (Appendix 1). These sites comprised farms considered as *typical* commercial medium-scale pig farms and sites connected to pig waste reclamation, for instance composting sites. Nonetheless, visits to farms sites had a degree of purposive sampling in the sense that all visits were arranged and intended to cover medium-scale farms as defined by the Thai Pollution Control Department (Ministry of Natural Resources and Environment [MNRE], 2005). In any case, all sites visited had a degree of heterogeneity since all differed in some aspects, for instance in the environmental management in place. At the same time, as addressed in this thesis, placing a farm within a given scale of production is not straightforward. Finally, informal conversational interviews during field visits provided additional valuable information.

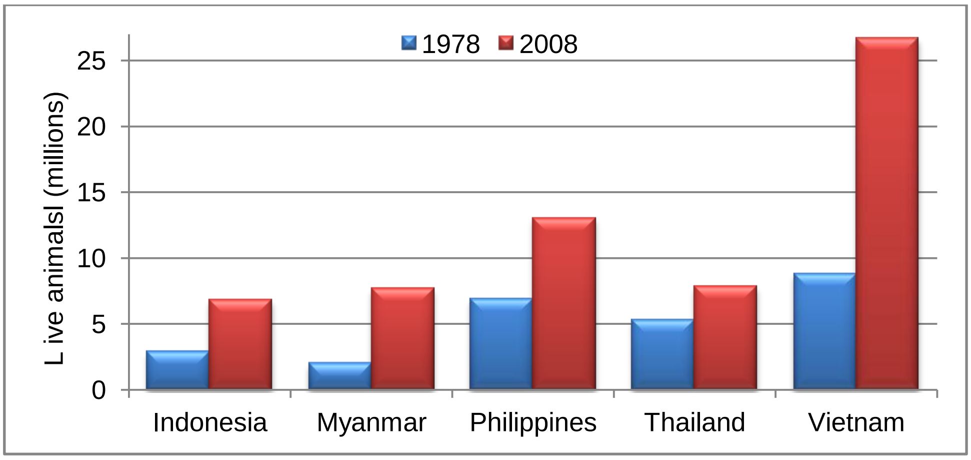
Qualitative data from primary sources was also obtained from expert sampling. A total of seventeen experts (Appendix 1) from various fields related to livestock and environment responded in person or via e-mails to open-ended interviews over the topic of animal waste use in agriculture. In the latter case [e-mail] experts were contacted for specific inquiries only. Interviews with experts were semi-structured around one topic: the use of pig manure in agriculture as a form of animal waste management. A description of the research topic was provided in written from which discussions followed. Although most often the interviewing process allowed an open-ended interview, it was not always possible to obtain conclusive statements from the interviewees and only occasionally were interviewees asked direct questions about their opinion on how to include informal practices on agricultural reclamation into present environmental frameworks and possible options for legal standards.

2. BACKGROUND AND FINDINGS

2.1 Growth of Pig Production in Southeast Asia

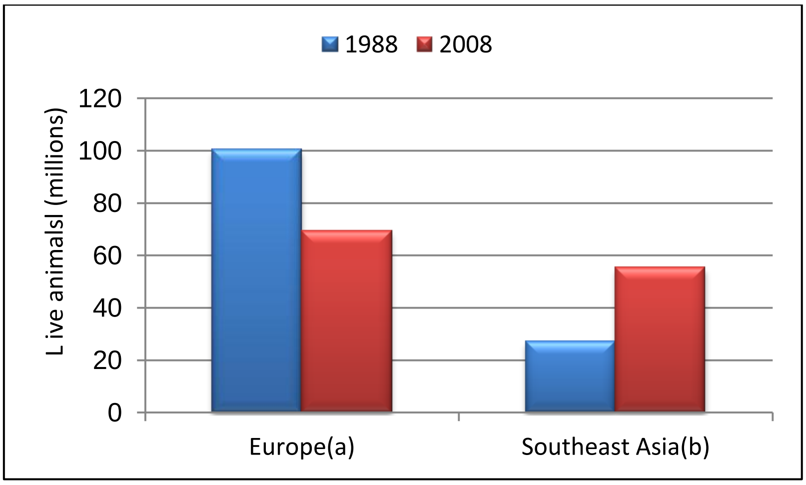
Southeast Asia is undergoing a transformation in animal production. An analysis of pig production in Southeast Asia (SEA) in the last 30 years reveals a considerable expansion of production (Figure 1). This is especially remarkable when compared against selected countries in Europe where production has declined in the same period of time (Figure 2). Moreover, in SEA, this growth does not only apply to countries with large animal production, but also to small producers. Data drawn from statistics data sets compiled by the Food and Agriculture Organization of the United Nations (FAO) (FAOStat, 2009) shows that Cambodia and Lao PDR, comparatively small producers in the region, also show a considerable increase in pig production.

Figure 1: Change in pig production in selected countries in Southeast Asia from 1978 to 2008. Adapted from FAOStat (2009).



One country where pig production has clearly increased is Vietnam. From 1978 to 2008 Vietnam's pig production tripled, surpassing Germany as the world's 4th pig producer since 2008 to present (FaoStat, 2009). In fact, as represented in Figure 2, trends in Germany and most countries in Western Europe (mainly within the EU), except Denmark, France and Spain, show a decline in pig production between 1988 ad 2008 in contrast to the increase in SEA region. This is significant because Germany or Poland are actually in the world's top ten pig producers (FAOStat, 2009) with some change in their ranking for earlier years.

Figure 2: Comparative change in pig production in selected countries in Southeast Asia and Europe from 1988 to 2008.
Adapted from FAOStat (2009).
(a) Germany, Romania, Hungary, Poland, the United Kingdom and the Netherlands.
(b) Thailand, Myanmar, Philippines and Vietnam.



Although this data is insufficient for a causal analysis and, moreover, production might have moved to neighbouring countries and not necessarily outside Europe, it leads to the question over whether production in Southeast Asia only responds to domestic or regional demand (Devendra, 2006), or perhaps, at least partially, also responds to the Pollution Haven Hypothesis referred earlier in this thesis; if not at present, in a near future. Furthermore, chicken production in Southeast Asia shows even more noticeable growth patterns, with more than a nine-fold increase in Indonesia, four-fold in Thailand and three-fold in Vietnam, for a similar period as mentioned above for pig production.

Nonetheless, countries might not follow the same pace in the industrialisation of production. In this regard, whereas Vietnam production has greatly expanded in absolute terms, Xuang Tung et al. (2005), the study reflected in Tuan et al. (2006) or Vu et al. (2007) show that there has not been a large scaling up in the size of operations or structure of production. Xuang Tung et al. (2005) reports that by 1994 only 2.2% of farms kept over six pigs, reaching 7.9% by 2002 with 548 commercial pig farms with at least 100 pigs. Another sign that there has not been a large scaling up in the size of operations at regional level can be seen in the way Vu et al. (2007) defines a medium-scale farm, with 19 to 99 fatteners / 5 to 19 sows, in a survey on manure management on pig farms in Northern Vietnam. However, as this thesis reflects, in the case of Thailand the definition of a medium-scale farm could easily account for 100 sows.

This difference in the number of sows in the definition of medium-scale farms is because, in contrast to Vietnam, production in Thailand has scaled up to bigger holdings. According to Falvey (2000), in 1993 over 50% of all commercial pig farms had more than 100 heads and, according to Caldier (2005), interpreted for year 2005, 50% of commercial farms had over 1000 heads. This data accords with Rattanarajcharkul et al. (2000), Delgado et al. (2003), Gerber et al. (2005) and Gerber & Menzi (2006), who refer to the intensification of pig production in Thailand.

While the environmental situation from the scaling up of production exists and challenges farmers and policy makers (Cloutier et al., 2003), in both developed and developing countries (Martinez et al., 2009), the environmental cost of pig production might be severe in a country with characteristics like Thailand, where production has not only increased in absolute terms but also in terms of farm size and structure of production, and, in a region where production is likely to continue growing (Hoffmann, 1999; Kristensen et al., 2004; Steinfeld et al., 2006; Tisdell, 1998). Moreover, this development in production takes places under limited environmental control, as addressed in this thesis in the case of Thailand, and shown in the report by the Global Environmental Fund (GEF, 2005), Gerber & Menzi (2006), Gerber et al. (2008) or Vu et al. (2007) in general for the region and other countries therein. These conditions make Thailand an appropriate case study for this thesis.

2.1.1 Scaling up of Pig Production in Thailand

In the last decades, Thailand has seen a rapid social and economic transformation (Goss & Burch, 2001). In this transformation, animal production has developed from traditional village level production to industrial intensive production (Tisdell, 1998; Gerber et al., 2005). Karen (1985) and Mensch (1986) show indicative case studies on how this initial scaling up of animal production took place by launching new farms or transforming existing ones through rural development projects often guided by agribusinesses corporations such as Charoen Pokphand Group. Originated in 1921, Charoen Pokphand Group is nowadays the biggest agribusiness company in Thailand and one of the largest in the world. Karen (1985) provides an example on how the Charoen Pokphand Group contributed to the development of larger operations from traditional farming.

Interviews with Sociologist Dr Naritoom (personal communication, September, 2008) and Mr Lohawatanakull, Vice Chairman of Charoen Pokphand Group (personal communication, October, 2010) sustain the view on the role of agribusiness corporations in supporting changes in production, directly, or by creating synergies in the industrialisation and vertical integration of independent pig farms into market chains controlled by agribusiness. For instance, according to a pig farmer interviewed during fieldwork in Yasothon Province (Field site 2, Appendix 1), the market structure provided by agribusinesses groups facilitated the establishment of the farm and its incorporation into the production chain. One reason why this information is important is because, according to Dr Naritoom (personal communication, September, 2008), and confirmed by Mr Lohawatanakull (personal communication, October, 2010), agribusiness firms advice farmers on environmental management. Interestingly, according to Dr Naritoom (personal communication, September, 2008), this might cause compliance agencies to overlook farms under corporate agreements because these farms might be considered as already receiving environmental guidance from corporations. The above-mentioned field site in Yasothon province actually had a well planned waste management system in place if compared to other field sites visited. Nevertheless, according to the farmer from Field Site 2 (Appendix 1) and confirmed by Dr Suthanaruk and Dr Woraporng from the Thai Pollution Control Department (personal communication, August, 2008), the implementation of environmental management and compliance remains entirely a farmer's decision and task.

Focusing back on the scaling up of production in Thailand, it is not straightforward to outline the structure of production in terms of farm size. The reasons are that, on one hand, the various organizations working on pig production, e.g., Department of Livestock Development, Pollution Control Department and the private sector, use different systems and categories to study and record production; and, on the other hand, at least partially, because of the natural complexity in the dynamics of pig production. This complexity is probably one of the reasons for the various ways data is found in literature.

A brief analysis of the data available shows that in Thailand, according to Falvey (2000), by 1978 86% of pigs were raised in backyard enterprises; of this, only 4% of farms kept over 110 heads. However, as seen earlier, the same author reports for 1993 over 50% of all commercial pig farms with over 100 heads and 13% over 1000 heads. Finally, in more recent data, figures reported by Caldier in 2005 point to about 50% of commercial farms with over 1000 sows.

Pig production figures for the year 2006 by the Department of Livestock Development (Table 1) show total number of pig farms by farm type, fattening and breeding (i.e., piglet and sow respectively to farm type). This official data (DLD, 2006) excludes farms with less than 50 piglets or 10 sows, suggesting therefore that contribution by small farms to total national production is negligible. However, this data (Table 1) also shows the considerable drop in farm numbers between smaller commercial operations and the large ones in the range presented. This leads to the fundamental but complex matter of how to characterize the structure of production in terms of distribution of operations. On one hand, scales should allow the categorisation of production and environmental management practices because both might depend on farm-size; on the other, scales have to allow a projection to policy level.

Table 1: Thailand's pig farming in 2006 presented by farm size and type and the equivalent in Livestock Units. Data exclude farms below 50 piglets and 10 sows. Adapted from DLD (2006).

Type of farm	Number of Animals	LUs (calculated)	Number of farms
Fattening farms (piglet)	50-500	6-60	4039
	501-1000	>60 – 120	965
	>1000	> 120	626
Breeding farms (sow)	10-50	3.4-17	24969
	51-200	>17 to 68	2191
	201-500	>68 - 170	649
	>500	>170	500

Despite data limitations of secondary data sources for a cross evaluation of the production structure, data from the Pig Magazine (2004) projected to national production using data from FAO Statistics (FAOStat, 2008) for the year 2004 (Table 2) supports the view that commercial medium-sized farms, measured in numbers of heads, seem in both cases, with and without excluding smallest farms (Table 1, 2) the most dominant farm-size in production.

Data (Table 2) shows that, whereas about 50,000 farms constitute for more than 80% of all pig farms in Thailand, this category of small farms only account for 15% of domestic production. In contrast, about 75% of total production originates in farms with 50 to 5000 heads in stock, yet only a few keep over 5000 heads. One limitation of this data, however, is that there is no information on the type of farm and therefore data comparison with other sources (for example with Table 1) is limited. In this case (Table 2), this thesis assumes that numbers are aggregates of commercial breeding and fattening farms and the combination of both.

Table 2: Indicative distribution of pig farms by size in stock and share in total production in Thailand. Based on data from the Pig Magazine (2004) projected to national production using production data from FAO Statistics (FAOStat, 2008) for the year 2004. Provided for guidance only. Calculations based on estimations.

Number of Farms	Stock (Live animals)	Percentage of total number of farms	Percentage of national production
48462	< 50	83 %	15 %
6618	50 – 500	12 %	20 %
2036	500 – 5000	4 %	57 %
154	> 5000	1 %	8 %

Although Table 2 is provided only for indicative purposes and data comparison is limited, it draws attention on one matter this thesis is after. This is that data does not actually show a particularly large production or growth in Thailand in comparison to other countries in the region, such as the Philippines or Vietnam (Figure 1); however, data shows that scaling up of production has led to a structure of production centered towards medium-scale commercial farms. Moreover, adopting the definition of medium-scale farm by the Thai Pollution Control Department addressed later in the text, in Thailand, there is evidence that within medium-scale farms, smaller farms are more abundant than bigger ones (Figure 3).

Figure 3: Structure of pig production in Thailand by farm-size within the medium-scale group (PCD- defined) (MNRE, 2005). See Table 3, pig farms measured in LUs (60 to 600). Data retrieved from www.netmeter.org/en/biogas(accessed 19 April 2010).

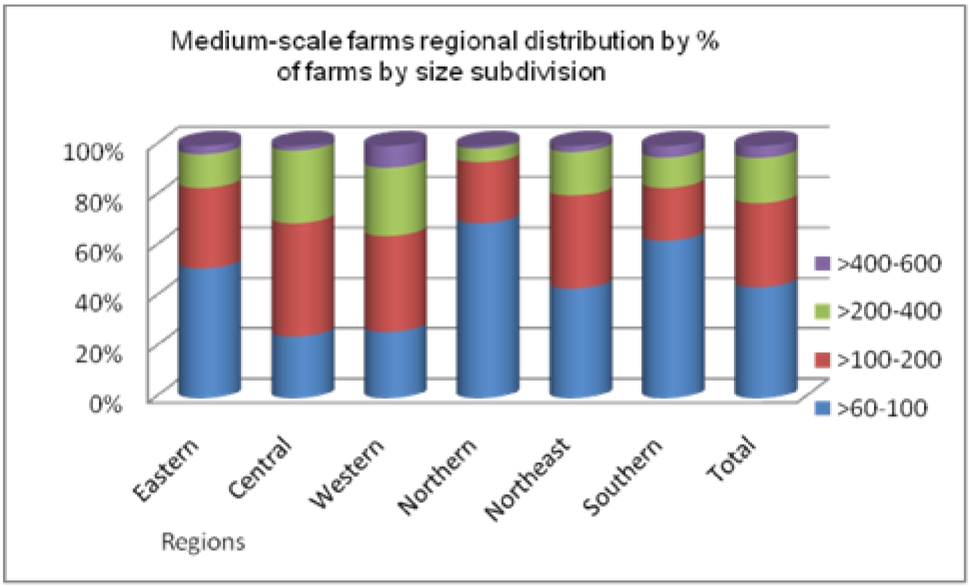
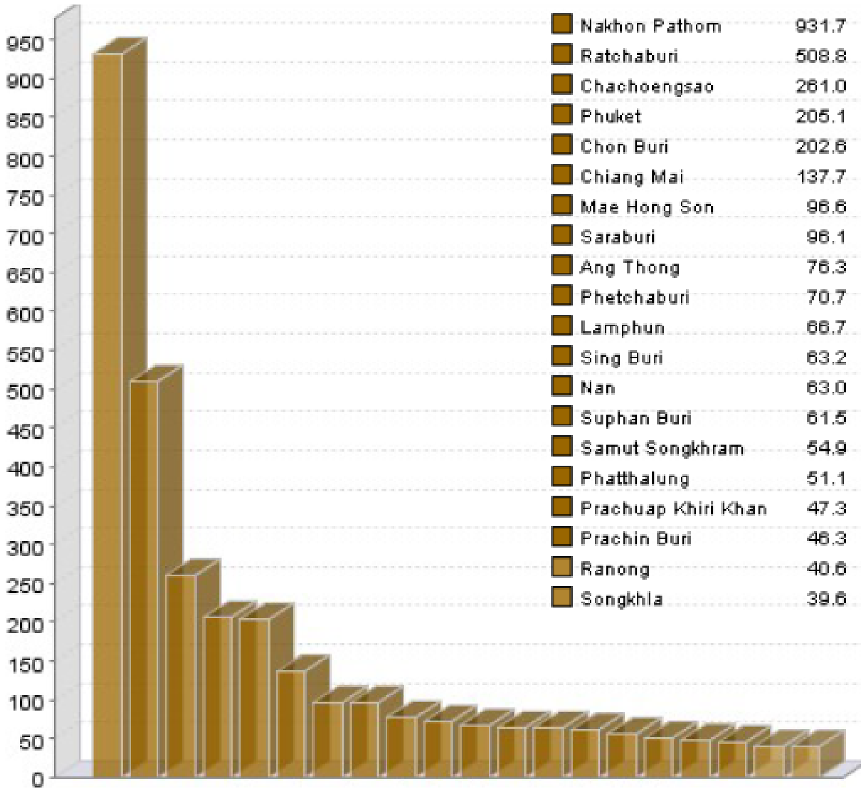


Figure 4: Pig production density in live animals over agricultural land (head/km^2) by provinces in Thailand (year 2000). Source: Global Livestock Production and Health Atlas [GLIPHA] (2007). Note that the three top provinces are in the proximity of Bangkok City.



In conclusion, the analysis of data shows a scaling up in the size of farms in terms of number of animals leading to a structure of production centered towards middle-scale operations. This scaling up is matched by a geographically spatial concentration of production (see Figure 4). One example is how pig production concentrates nowadays around the proximity of the biggest city, Bangkok, as shown in Figure 4. Therefore, this scaling up can also be interpreted as leading to a geographically spatial concentration of production. Consequently, this structure of production results in large volumes of localized animal waste.

Indeed, densities in terms of number of animals and agricultural land could be interpreted as a proxy of the regional capability to utilize pig solid waste in agriculture. The higher the density, the less likely it is for agricultural farmers to use up all the pig solid waste produced. However, this capability might also depend on the level of animal farming and agricultural land availability in adjacent provinces and, as this thesis later observes, on several other factors.

The next section addresses how pig production has developed in a structure beyond the small-farm threshold in terms of environmental management. As a result, a large number of pig farms require, in theory, specific environmental management, as reported in Gerber (2006), regardless of their regional location.

2.2 Animal Waste Reclamation and Policy Instruments

Extensively covered by Steinfeld et al. (2006), numerous countries are experiencing a scaling up of animal production which has been recognised as the Livestock Revolution (Delgado et al., 1999a) for its similarity with the Green Revolution. Although contested by Pica-Ciamarra & Otte (2009), the analogy with the Green Revolution draws from structural changes associated with markets (Delgado & Narrod, 2002) and environmental risks derived from the increase of production in systems with high external inputs.

Environmental impacts from livestock are already a global problem commonly addressed in the media by quoting estimations of green house gases (GHG) production drawn from Steinfeld et al. (2006:112) who reports that 18% of the global GHG originate from livestock production. On the other hand, as Steinfeld et al. (2006:262) also reports, drawing from Food and Agriculture Organization of the United Nations [FAO] (2005), impacts from livestock extend beyond the production of GHG and include various other potential environmental detrimental effects aggravated by deficient waste management.

One notorious example of pollution from animal farming is the Chesapeake Bay in North America. According to media sources, 25% of the Bay's nitrogen and phosphorus pollution originates from runoff from animal manure (Fahrenthold, 2010, March 3). This case is an example of what is no longer a global emerging environmental threat, but an ongoing one in many parts of the world. Similar to the case in the Chesapeake Bay, estimates in the Mekong Delta in Southeast Asia point to 16% nitrogen overloads originated from animal manure (Ifft, 2005) and the pollution of regional coastal waters (United Nations Environmental Program [UNEP], 2007).

Deficient animal waste management has been recognised in countries with well-established environmental and agricultural governing bodies. In the United States (USA), the National Environmental Protection Agency [USEPA] has acknowledged "*minimal or no treatment [is undertaken] before the wastes are disseminated into the environment*" (USEPA, 2004). This situation is not necessarily because of a lack of regulations in this country. Indeed, it is rather because environmental regulations in animal farming are particularly difficult to implement. A report by the United States Congressional Research Service (CRS, 2008) notes how regulations often exempt agriculture from complying or are arranged in a way that farms can escape them. In Canada, Beaulieu (2004) reports about regional cases that show up to 80% of farms with less than 500 pigs with no formal manure management plan. Moreover, government reactions at policy level in countries with high levels of environmental governance include moratoria for new operations as Moyer et al. (2008) refers to in the case of Manitoba, Canada.

Environmental pressure from livestock can also be seen, as noted by Cloutier et al. (2003) in the case of Mexico, not only as a result of the scaling up of production, but also due to weak environmental policies; or, as seen by Moyer et al. (2008) for the case of pig farming in Manitoba, Canada, due to unsuitable conventional regulatory approaches. According to Moyer et al. (2008), farmers themselves demand "*regulations to legitimize [their] activities*" (Ibid).

Regulations over animal waste management are generally elusive and controversial (CRS, 2008). Farmers are likely to oppose hard-line norms such as proposals in the United States to classify animal manure as hazardous waste (American Farm Buerau Federation [AFBF], 2007). As noted in an interview with Dr Kongsricharoern (personal communication, September, 2008), farmers prefer open-ended legal frameworks to legally binding standards as well as they prefer those environmental management options with the lowest economic cost. This is confirmed by economic research on pig waste management in Mexico (Drucker & Latacz-Lohmann, 2003) pointing to land application of animal wastes as a preferred option to command-and-control legislation based on farm effluents.

Land application of animal waste can refer to both disposal and recycling of manure as a resource in agriculture (*cf* Steinfeld et al., 2006:69). Consequentially, both become a form of waste reclamation contingent to land availability, particularly, agricultural land availability. The concept of animal waste reclamation is based on the use of manure in agriculture as fertiliser and, as noted by Gerber & Menzi (2006), also as soil amendment. The use of manure in agriculture originates in its content in nitrogen and phosphorous in addition to organic matter and other nutrients. From an environmental management perspective, the key point is that, in the scaling up of production, specialised animal farms do not necessarily keep sufficient land to manage all the waste they produced, resulting therefore in nutrient surpluses and pollution (FAO, 2005; Delgado et al., 2003).

From waste management practices in which waste reclamation conceals disposal, to ideal cases in which waste is efficiently managed by reclamation (Schröder, 2005), there is going to be a range in the degree that waste reclamation practices actually function as animal waste environmental management. Along this range, there are going to be substantial drawbacks because such practices can bear environmental impacts; apart from nitrogen and phosphorus overloads, impacts might include water and soil pollution by heavy metals, particularly cadmium and arsenic (Prachoom, 2006; Simmons et al., 2008; Zarcinas et al., 2004; Li & Chen, 2005), soil salinisation (Ju & Kou., 2007; Moral et al., 2007), pathogens (Holley, 2006) and the presence of pharmaceutical residues from modern husbandry (Venglovsky et al., 2009). Finally we must add the social factor in the acceptance by neighbouring communities [to animal farm or reclamation sites] and the public perception on the safety of manure (Burton, 2009).

Above all, based on economic modelling (Park et al., 2006), land availability remains a global geographical factor in the distribution of pig production based on its function in waste elimination. Accordingly, livestock production should be affected by the environmental significance of agricultural land availability, specifically, for the sanitation of animal waste and as much as to determine the distribution, location and therefore structure of production at intra-national or even international level.

In this fashion, notwithstanding the well-known agricultural value of manure, its environmental significance in the environmental dynamics of new livestock production scenarios is influenced by, first, the absolute location of livestock production driven by the specialisation and scaling up of production (FAO, 2005, Gerber & Menzi, 2006; Gerber et al., 2005; Delgado & Narrod, 2002) and, second, the relative location of production in relation to agriculture. These two factors might lead to geographical imbalances between location of waste production and locations where waste might be needed in agriculture (Gerber & Menzi, 2006; Gerber et al., 2005). Conclusively, the spatial concentration of industrial operations provides numerous environmental management challenges which have yet to be fully understood and legislated.

In fact, a literature review over livestock and environment reveals multiple uncertainties concerning agricultural reclamation of animal waste. What are the ideal application rates from an agronomic perspective? How much from an environmental perspective? How can environmental standards be developed and implemented? As Centner & Newton (2008) address, Is there a threshold between agronomic and environmental benefits? This threshold would signify the line between waste disposal and agricultural use of manure, and respectively, between livestock environmental mismanagement and animal waste reclamation as part of livestock and farm environmental management.

These uncertainties affect the development of environmental governance of animal production and partly originate in the limitations of science and management systems to understand and integrate biogeophysical and socioeconomic interactions, particularly when the issue of *values* in sustainability is paramount (Ludwig, 2001).

One common instrument for the abatement of pollution from livestock is the use of effluent standards for animal farms (see for instance Steinfeld et al; pp 246**)**. However, wastewater effluent standards do not provide a universal solution. For instance, discharge standards do not directly contemplate diffuse pollution [2] (Ibid) and neither do they contemplate the timeline of discharges. Placed within an ecosystemic approach, Total Maximum Daily Loads (TMDL) (USEPA, 2001) might provide a more realistic parameter. However, regulations based on TMDLs are not free from uncertainties in itself as parameters measuring environmental processes (Ludwig et al., 2001).

In the complexity of regulating effluents, there is also the matter of land-based standards for manure use in agriculture. Too restrictive standards based on one nutrient loads (e.g., nitrogen) might be seen in socioeconomic terms as limiting economic growth or development, particularity under low land availability by livestock farmers.

At any rate, most countries keep some form of norm applicable to animal waste management (Heinz, 2003; FAO, 2005), whether embedded in public health policies, animal sanitation or environmental standards. Regulations to control pollution from animal waste use in agriculture are often based on nitrogen (N) and phosphorus (P) because of their value as agricultural nutrients and also as potential pollutants and therefore N and P are commonly used as indicators in agronomy and the environmental management of both agriculture and livestock (Meynard et al., 2002; Schils et al., 2007; Bockstaller et al., 2008; 2009). These two nutrients signpost the threshold between the use of manure as a resource in agriculture and as disposal; and, therefore, between its function as waste reclamation or disposal. Nutrient balance models based on N and P in their various forms are therefore commonly used in waste management tools and policy instruments for the regulation of waste use in agriculture, such as MANNER (2000), Manure Nitrogen Evaluation Routine, used in the UK.

[2] *Diffuse, or non-point source pollution, differs from point-source pollution in that the former takes place over wider spatial and time scales e.g. excessive fertilisation, a phenomenon difficult to monitor and localise in time and space.*

As mentioned earlier in this text, the European Union provides an example of land-base standards for animal waste use in agriculture. The Nitrates Directive 91/676/EEC represents a policy instrument in an attempt of environmental governance over animal production to prevent excessive nutrient loading to the environment (*cf* FAO, 2005). The case of the Nitrates Directive (Nitrates Directive 91/676/EEC) provides an example of standards limiting land application of manure by kilograms of nitrogen per hectare per year. However, its implementation has been controversial because of uncertainties in establishing manure application thresholds under different biophysical conditions in different geographical locations (DEFRA, 2007; 2008). These uncertainties have caused some members of the European Union, the Netherlands (Schröder & Neeteson, 2008) and United Kingdom (UK) (DEFRA, 2007; 2008) to apply and obtain derogations.

The use of compensation payments is a common policy instrument in the environmental governance over agriculture in the EU (Heinz, 2003). In the case of the UK, the enforcement of the Directive is mostly based on compensation payments in Nitrogen Vulnerable Zones. In the UK, the policy is then implemented with the support of nutrient management tools, as the above-mentioned MANNER (2000) model. Nonetheless, the UK has developed a less restrictive standard, 250 Kg N Ha/y, (DEFRA, 2008) instead of the 170 Kg N Ha/y defined by the original directive. Furthermore, DEFRA supports research to validate higher application rates (DEFRA, 2007) with a view to reduce the economic impact of such regulations on the livestock sector.

These models support the implementation of manure management plans as part of the environmental management of the animal farm, and can be developed to incorporate not only the characteristics of manure (i.e., nutrient content) but also the characteristics of the agricultural land, (i.e., soil types), crop types and other environmental variables (i.e,: rainfall). All these factors can be incorporated into models to calculate manure quantities and land requirements under a given set of conditions. Some examples of these models are: MANNER (MANNER, 2000) in the UK, AMANURE (Jones, 1986) and MMP (Purdue University, 2008) in the USA; Nutmon-Monqui (Nutmon, 2003) developed in the Netherlands but designed for tropical farming systems; or NuFlux (Fachhochschule, 2006), which has been used by international agencies in Southeast Asia (Menzi et al., 2002). The latest development of NuFlux has led to the model STRAW[3] (2010), Support for the Treatment and Recycling of Animal Waste.

[3] *Test version provided by Dr Gerber et al 2010 in personal communication, June, 2010.*

2.3 Pig Production and Waste Management in Thailand

One of the first environmental reports at the onset of intensive animal farming in Thailand to explicitly mention a commercial pig farm (McGarry, 1972) shows that environmental management was essentially nonexistent. After all, according to Falvey (2000), by 1978 86% of all pig stock was in backyard farming and only 4% of farms kept over 110 heads. However, as shown in the environmental report by McGarry (1972) and case studies by Karen (1985) or Mensch (1986), specialization of production was on its way. Anticipating the detachment of animal and crop production and consequent environmental impacts, in 1977 Thailand launched the concept of *livestock state* (Jesdapipat, 1998). Pig farms were grouped with mango plantations for manure recycling and the integration of animal farming with agriculture. Although success was limited (Ibid), in the late 1990s the Thai Pollution Control Department revisited the idea with a feasibility study for establishing a swine farming estate (Chunkao, 1997).

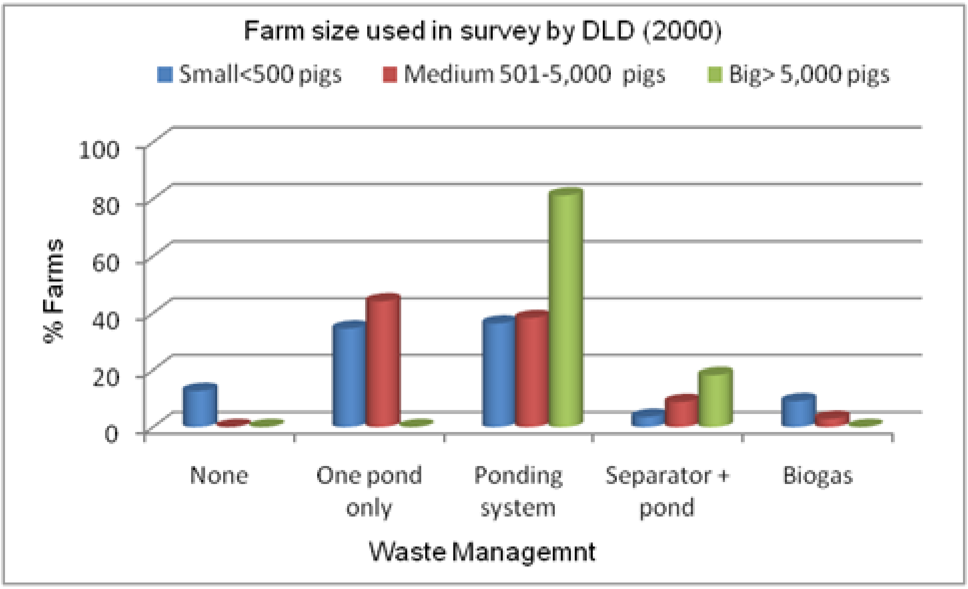
At the same time, Thailand conducted studies under the projects of Area-Wide Integration Framework (AWI) (Hadiwigeno, 1998), a project coordinated by the Food and Agriculture Organization of the United Nations. This project has nowadays given way to the Livestock Waste Management in East Asia program (LWMEA) (LWMEA, 2009). AWI was an environmental framework that addressed the question of spatial distribution of livestock production and the development of policies in response to the environmental impacts from animal production (*cf* Steinfeld et al, 2006:262). The working premise was the growing detachment of animal production from agriculture and, therefore, AWI projects seem to have targeted the spatial distribution and integration of intensive livestock operations in agriculture (*cf* FAO, 1998) as shown in case studies on pig production in Vietnam (Thi Dan et al., 2003), in the vicinity of Bangkok (Jesdapipat, 1998) or Eastern Thailand (Rattanarajcharkul et al., 2000).

These studies in Thailand took place along a growing risk of pollution from industrial and municipal wastewater from urban development in the proximity of Bangkok. One of the areas visited during this thesis' field work was in the lower Thachin River watershed, an area heavily associated with the risk of pollution from pig waste (Schlaffner, 2006). Pollution in parts of the river reached the level of crisis in the year 2000 resulting in massive fish kills (Dr Simachaya, personal communication, August, 2008, comments on Simachaya, 2003). According to Simachaya (2003), pig farms were a major source of pollution affecting the river in this area in Nakhonpathom province, a province with the highest density in pig production over agricultural land (see highest bar in Figure 4).

Preceding the environmental crisis in the year 2000, the Thai Pollution Control Department had commissioned a wastewater management study (see MACRO, 1995) covering this area of high pig farm density. Results pointed at pig waste as partially responsible and included a project for a centralized animal waste sanitation system (Ibid). Later proposals for the same geographical area would suggest central pig waste management facilities for biogas production (Yuttitham et al., 2003). It is however unknown to what extend these projects, swine state, centralized waste management and central biogas facility, have been implemented. Interviews conducted did not provide additional information.

In terms of technology and practices in the environmental management of pig farming in Thailand, in the year 2000, the Department of Livestock Development released data from a national survey on pig waste management practices (DLD, 2000). Results of the survey shown in Figure 5 reveal retention ponds as the most frequent waste management practice across all farm sizes. Furthermore, data shows how waste management practices depend on farm size. Of those within small and medium-size farms using retention ponds, about 50% were stated with *one pond only* and only a small percentage with mechanical separator of solids. The majority of large farms had more than one pond and about 20% used mechanical separator of solids.

Figure 5: Waste management in pig farms in Thailand by percentage of farms in farm-size category. Figure shows how waste management practices depend on farm size. Adapted from DLD (2000).

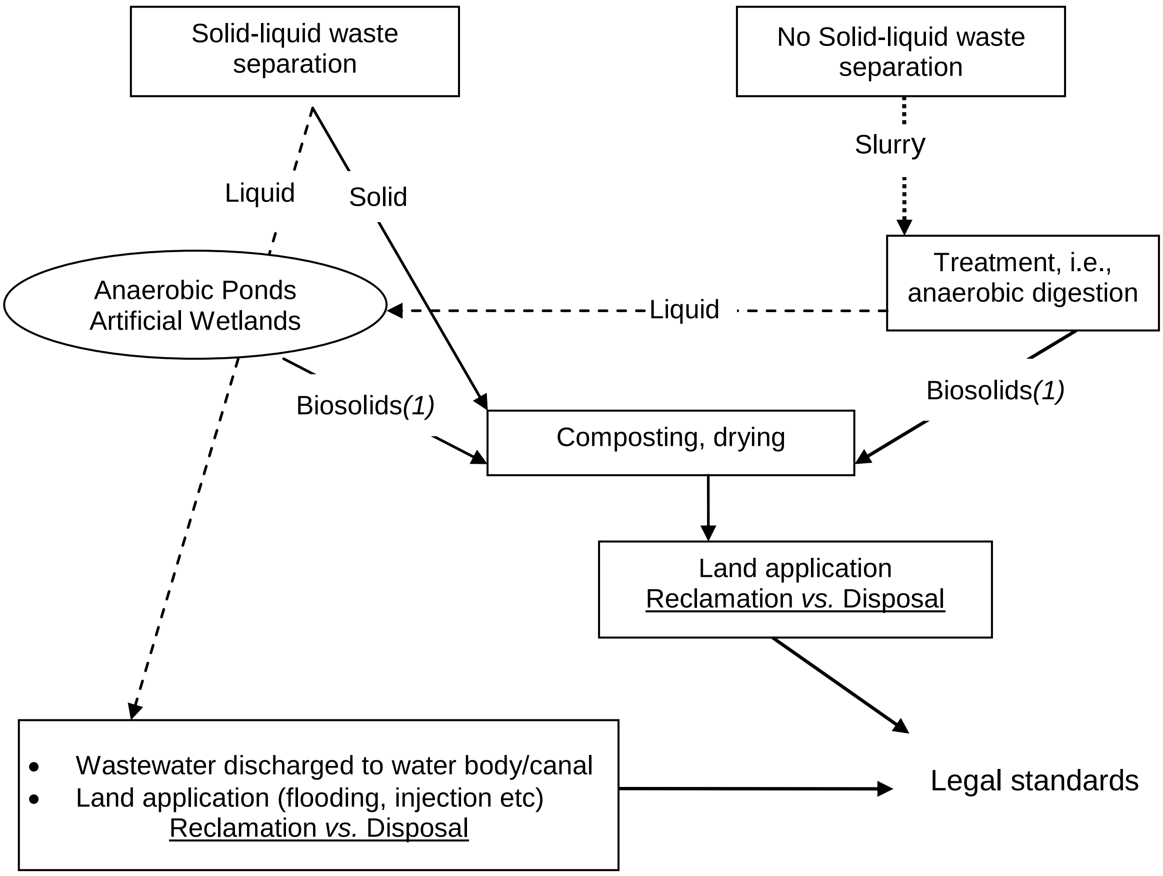


The above-presented information on waste management raises two important questions: the first one is about the way farms were categorised in terms of farm-size; the second one is about how waste reclamation fits into waste management alternatives in the survey, since waste reclamation as such was not included. With regard to the latter, the survey shows common use of retention ponds and low use of mechanical separation in slurry management. This points to the practice of in-house waste separation. In-house waste separation is identified as removal of solids from the pig pens before solids are mixed with wastewater and become what is commonly known as slurry. In Thailand, wastewater is mainly produced from washing pigs and pig pens. Wastewater is usually conveyed to retention ponds. The typology and number of ponds are indicative of the type and level of waste management in a farm. The use of ponds can develop to complex systems (Photo 4 & 5) such as combinations of anaerobic, facultative and aerobic lagoons or artificial wetlands. When there is only one pond, usually known as retention pond, it is generally assumed it has anaerobic conditions due to nutrient loads. Nutrient overloads in *one pond only* systems are likely to occur, particularly, under condition of no solid-liquid separation. Therefore, systems based on *one pond only* are likely to provide insufficient treatment.

A report by the Pollution Control Department [PCD] (1999), whose account may have been drawn from the above-mentioned survey conducted by Department of Livestock Development (DLD, 2000), reports waste separation in 78% and 64% of breeding and fattening farms, respectively. Therefore, separation seems to be a common practice in Thailand at all levels of production. Otherwise, ponds would rapidly fill up with solid waste. Indeed, in a survey conducted in several provinces, including the above-mentioned Nakhonpathom province, Kiratikarnkul (2008) reports such situation from *deep ponds,* one of the waste management alternatives recorded and reported in 13.94% of farms. Other waste management alternatives included in the survey are: organic fertiliser, in 33.10% of farms; fish feed (use of manure as freshwater fish feed), in 14.98% of farms; a combination of biogas and fish pond, in 7.67% of farms; and biogas technologies, in 30.31% of farms. However, Kiratikarnkul (2008) reports that only 1% of biogas produced was used and around 83% was lost. It is important to note that, in the alternatives presented in the survey, *organic fertiliser* here corresponds to waste reclamation in agriculture. Moreover, ultimately, deep pond and biogas do not exclude field disposal or reclamation of waste in agriculture. In the case of deep ponds, waste might be stored with no separation and, therefore, eventually, ponds need to be emptied, at least theoretically. When such process occurs, waste might be simply disposed of to wastelands or used in agriculture. As well, biogas generation produces a digestate which also needs to be disposed of or used in agriculture.

Figure 6 below presents a scenario of pig farm waste management driving the environmental dynamics of pig production in Thailand. This diagram can be applied to a farm with a certain level of waste management and operating without or only with partial anaerobic digestion of waste produced. Waste management begins with the option of solid excreta removal by scraping manure from the pig house floor [in-house separation] (Photo 7) before animals and floors are flushed with running water. Solids removed from the floor are air-dried and in some cases composted. If there is no in-house separation at this stage, wastewater from washing the pens gets highly contaminated with excreta. In any case, wastewater is then conveyed to a pit or retention pond.

Figure 6: Scenario of pig waste management. Schematic representation of common waste management in confined pig farming in Thailand. Excludes no solid-liquid separation with waste conveyed to a deep pond as reported in Kiratikarnkul (2008). This figure illustrates how management of liquid and pig solid waste ultimately converge to a question of "reclamation vs disposal" translated to a policy level as legal standards.



(1) digestate.

As reported by Rattanarajcharkul et al. (2000), Gerber & Menzi (2006) and Kiratikarnkul (2008), pig manure is widely used in agriculture in Thailand, although, as pointed out by Gerber & Menzi (2006), in many regions of Thailand pig manure is less valued compared to manure from other livestock waste.

What is clear is that solid waste separation continues to play an important role in the environmental management of pig farms. Moreover, solid waste available from in-farm waste management practices makes reclamation possible as an agricultural resource. Experts and animal farmers (e.g., Dr Polpraset, personal communication, August, 2008) reported that crop and fish farmers often collect manure from animal farms. This creates collateral benefits for livestock farmers from trading, but also from the removal of waste, hence relieving pig farmers from the management of heavy slurry. The use of manure in fish farming is presently a common international practice and many scholars argue that if manure is properly treated for fish feed, it is not necessarily a negative practice (Schroeder, 1980; Edwards, 2000, 2002, 2005; FAO, 1980; Yijing et al., 1987; FAO, 2001). Nonetheless, Dr Chaiyakul informed in personal communication (September, 2008) that the use of pig manure by fish farmers is officially frowned upon by the Department of Livestock Development if conducted with raw manure.

Interestingly, Vu et al. (2007) reports that some pig farmers in Vietnam keep pigs only because of the value of manure as fish feed. At any rate, in agreement with Tuan et al. (2006) referring also to Vietnam, both researches show regular use of manure in agriculture and, like in Thailand, mechanical separation is rare. In the case of Thailand, according to the data presented (Figure 5), [slurry] mechanical separation mostly takes place in large operations.

At the same time, Tuan et al. (2006) reports that the solid waste fraction collected [not mixed with wastewater] presents higher levels of nutrients than the liquid fraction. This can be interpreted as a higher potential agricultural value; however, if mismanaged, it can also be interpreted as a higher potential for environmental impacts. Here lays an important setback in in-farm management of solid waste [manure]. As reported by farmers in several field sites and confirmed by experts, such as Dr Kongsricharoern (personal communication, September, 2008), solid waste may remain for a long time in the pig farms before it is taken away to agricultural fields or fish ponds.

At any rate, solid waste reclamation has tacitly become part of pig farming waste management. According to Dr Polpraset (personal communication, August, 2008), systems for slurry application such as slurry injection have not been implemented in

Thailand. The agricultural reclamation of pig wastewater as slurry seems to be rare with no literature clearly reporting the practice. This absence might be because of operational cost and uncertainty in agricultural value of treated pig slurry. On the other hand, as reported by Rattanarajcharkul et al. (2000), in some cases, pig farmers dispose wastewater from ponds to agricultural fields. This was confirmed during fieldwork where farmers reported the discharge of water from a pond system to a small rubber plantation meters away from the ponds and pig housing. It seems, however, that the practice was not regarded as fertirrigation[4] but as a way to safely dispose wastewater.

There is in fact a number of innovative systems utilising pig manure and wastewater because their fertilising value, a variety of practices interpreted here as indicative of the uncertainness surrounding agricultural reclamation of pig solid waste and the variety of methods. One noteworthy example is the development of Pig Manure Extract (PME) (Momngam et al., 2005) and which consists in letting pig manure set in water for a given time and then removed (Ibid). According to the main proprietor, Dr Kanto (personal communication, September, 2008), the use of PME in fertirrigation and as foliar fertiliser has yielded extraordinary results in cassava crops (*Manihot esculenta*) and a production pilot plant is under planning. It has not been concluded, however, what exactly accounts for such high yields. Cassava fields are usually not irrigated in Thailand (Onwueme, 2001) and high yields could partially be the result of supplemental irrigation (*cf* Oweis, 2005). Moreover, as observed in fieldwork and confirmed in expert interviews, for instance with Dr Kanto (personal communication, 2008) or Dr Duangpatra (personal communication, 2008), there is considerable diversity of practices in managing manure, including for example adding by-products from the cassava processing industry for allegedly added fertilizing effects. Dr Duangpatra informed (personal communication, August, 2008) that despite several studies (in Thai language, not consulted), it has not been possible to clearly pinpoint the agronomic benefits of using pig wastewater.

Agricultural reclamation practices are interpreted as the continuation of traditional agricultural use of animal waste and the agro-ecological recycling of nutrients. However, the significance of practices and processes conducted as traditional waste management has been transformed along with the scaling up of production. Under present production scales, the practice goes beyond its agricultural value because of its significance as waste management option for the pig farmer to deal with the large amounts of in-farm solid waste. Therefore, the agricultural use of pig solid waste, whether as fertiliser or soil

[4] *Fertirrigation refers to the use of irrigation water to deliver fertilisers to crops.*

conditioner, cannot simply be understood as a projection to larger scales from traditional small scales of production. On one hand, we cannot assume a direct scaling up of waste management to efficiently work in parallel to a scaling up of animal production; on the other hand, we cannot dismiss the environmental value of reclamation practices.

What requires investigation is how the scaling up of production, with the detachment of agriculture from animal production, specialization and spatial and farm-size concentration of production, has transformed the significance of waste management practices commonly understood as *traditional*. In this transformation, both physical and human processes contribute to the significance of waste reclamation in agricultural and environmental terms. An important question, therefore, is how these systems somewhat inherited from traditional practices have developed given the transformations to the industry and agriculture.

As addressed earlier in the text, one of the most important aspects in the environmental impacts from animal production is the geographical concentration and detachment from agriculture. Gerber (2006) studied the question of environmental impacts from pig production in Thailand by looking at farm location under a hypothetical scenario of full environmental compliance to present regulations on pig farming. The author reported that, notwithstanding a lower compliance cost for farms in rural scenarios, relocation –interpreted here as to areas with higher agricultural land availability— without complementary measures would not solve the pollution issue. In a later study, partially, at least conceptually, based on the AWI framework and NuFlux model by Menzi et al. (2002), Gerber et al. (2008) looks into the policy projection of the location-animal production nexus —applicable to decision making processes for new pig farms permits— and proposes the use of Geographical Information Systems to analyse the spatial distribution of production according to land requirements.

In this regard, the latest development has been the software STRAW or Support for the Treatment and Recycling of Animal Waste (Test version provided by Dr Gerber in personal communication, June, 2010). The program allows calculations of agricultural land requirements by using nutrients flows. It can by tailored according to several variables, such as type of livestock and crop. The development of STRAW can also be seen as a progress of international programs in support to the development of national policy frameworks to address the environmental management of livestock. Presently, the main policy for the environmental management of pig farming is the Pig Effluent Standards (MNRE, 2005).

2.3.1 Pig Effluent Standards

In line with Dr Simachaya's comments (personal communication, August, 2008) over the severe pollution events in the Thachin River —a river affected by high pig production west of Bangkok, in Nakhonpathom province (highest bar in Figure 4)—, the development of water quality policies and international cooperation contributed to the issuance of pig effluent regulations in Thailand. Not long before, the Thai Pollution Control Department (PCD) had commissioned a report, MACRO (1995), mentioned earlier in the text, which covered this area of high pig farming density. The report pointed at pig waste as a major source of pollution in the river and proposed a centralized animal waste sanitation system. This view corresponds to the finding in Simachaya (2003) which states that pig farming is major contributor to the water quality level in this river. Finally, the Ministry of Natural Resources and Environment [MNRE] issued an official set of standards for maximum values for effluents from pig farms (MNRE, 2005) (Table 3).

Table 3: Thailand effluent standards for pig farms. Source: MNRE (2005).

Parameters	Standard A Farms 60 to 600 LU	Standard B Farms > 600 LU
pH	5.5-9	5.5-9
BOD (mg/l)	60	100
COD (mg/l)	300	400
SS (mg/l)	150	200
TKN (mg/l)	120	200

Effluent standards for pig farms cover five parameters (Table 3) with two sets of values according to two farm-size categories. This brings back the question on how to classify farm-size. As addressed earlier in the text, using a system based Livestock Units the Thai PCD divides farm-size in three categories, large, medium and small (Table 4). There are, however, only two levels of effluent standards: A, for medium-size farms, and B, for large farms (see Table 3 & 4). As reported by Dr Warapong (personal communication, August, 2008), small farms, those below 60 LUs, are not obliged to comply with discharge regulations. As addressed earlier in the text, this measurement of farm-size scales develops from numbers of live animals (stock) incorporating farm dynamics for the calculation of farm-size in LUs. The inclusion of farm dynamics is crucial in the assessment of the size of a farm in terms of its environmental management because waste production is contingent to farm and pig production dynamics (e.g., farm main business: breeding or fattening).

An estimation of PCD categories in live animals (stock) by farm type and size (Table 4) shows the high variability that a medium-size farm can present in terms of number of pigs and only by these two factors.

Table 4: Farm size in livestock units (LUs) as defined by the Thai Pollution Control Department and equivalents (estimation) in stock by type of farm.

Farm size category	LUs	Estimate in stock (live animals) (1) by type of farm	
		Only Sow	Only fattened
Small	< 60	<176	<500
Medium	60–600	<176-1760	<500-5000
Large	> 600	>1760	>5000

(1) *Shown for indicative purpose only. First two columns describe the pig farm classification system in Thailand according to pig farm effluent standards by the Thai PCD (MNRE 2005). Next two columns provide an estimate in animal numbers. Note that farm conditions might include fattening pigs in addition to sows and piglets, animal weights vary and not all sows keep piglets at the same time. Reproductive performance of sows depend on several factors, such as sow parity and season (Tantasuparuk et al., 2000).*

Pig Effluent Standards apply to the effluent released by pig farms. As officials from the PCD explained, Dr Warapong (personal communication, August, 2008) and Dr Simachaya (personal communication, August, 2008), it is actually rather difficult to monitor effluents from a specific farm because there is the issue on where and when to sample. Pig effluent standards in Thailand are based on a set of pollution indicators at a given time and point and do not take into account effects of continuous or discontinuous discharges. Fieldwork visits to Nakorn Chaisri river canals (part of the Thachin river) and expert interviews reveal that discharges from pig farms depend on the time of the day and even the weather. Discharge standards do not, however, contemplate the time of the day when pick concentrations might take place. For example, in the case of fieldwork visits in Thailand, pick concentrations were reported by experts to occur when pig pens are washed, usually early in the morning. As observed in fieldwork and discussed with farmers, this is likely to happen around the same time in all farms in a given area, consequently, water canals near pig farms become pig wastewater collectors (Photo 1).

Moreover, discharge standards do not directly address the question of diffuse pollution from waste transfers to agriculture and neither do they cover the possible nutrient losses from in-farm accumulation of manure.

On the other hand, Total Maximum Daily Loads [TMDL] USEPA (2001) is a concept applied to environmental standards in an attempt to include the conditions of the water body where effluents are released. Therefore, the focus is rather on the conditions of the water body than on effluent levels. For this reason, a similar concept might be a suitable perspective when the pollution of canals can be seen by naked eye as witnessed in fieldwork, a phenomenon highly related to the spatial concentration of farms and farms size.

2.3.2 Production Scales by Effluent Standards

As shown earlier in the discussion, in order to address environmental questions in pig farming it is essential to describe the production structure as well as define the scale of production in terms of farm size. This is important because, as discussed elsewhere in this thesis, environmental practices depend on the farm size and subsequently the environmental dynamics and the significance of such practices depend on the scale of production. Moreover, present environmental regulations are divided by farm size. However, defining and deciding to what size category a farm belongs depend on the farm production dynamics (i.e., number of rotations a year or weight to slaughter). Same stock in terms of head count could result in a different quantity and quality of waste upon depending on farm characteristics, including commercial arrangements, type of operations (breeding, fattening), proportion of sows to fatteners or the weight animals are removed from the premises. All these factors drive farm size, might affect the conditions for waste management and influence the level of compliance with effluent standards..

In Thailand, effluent standards apply to production scales by using Livestock Units (LU). LU are based on weight (kilograms) calculated by the type of animal in terms of its characteristics for production. In Thailand, 1 LU corresponds to 500 kg., with the number of LUs in a farm calculated by the number and type of animals. Sows count as 170 kg. per head, nursling pig as 12 kg., and fattened pig as 60 kg. per head (MNRE, 2005). The use of LUs facilitates a more realistic classification of farms in terms of their environmental dynamics and waste management. However, pig farm dynamics are complex and LUs do not account for all factors affecting waste management.

Moreover, within a category, the is a wide range when numbers are transformed from LUs to stock. Therefore, reaching an accurate estimate of waste produced to plan the waste management or assess potential environmental impacts is problematic. This is particularly important when planning the design and implementation of technological solutions, as it is the case of waste treatment by biogas generation. Fine tuning of anaerobic digestion reactors for biogas and energy production might become too intricate for medium-scale commercial farms with high variability in waste produced and low expertise in biogas production.

This is interesting because data shows a scenario of pig production concentrated in the a farm-size at medium-scale (see Table 1, 2 and Figure 3). Data also reveals that despite the scaling up of production, there has not been an absolute shift of production to large operation and very large farms (over 5000 sows) account for a relatively small share of total production and farm numbers (Table 2). In agreement with Gerber et al. (2005), the overall image is that small holdings have become marginal in terms of total pig production in Thailand.

Indeed, if the medium-scale farm, as defined by the PCD, is used as reference, a cross analysis of data on the structure of production in Thailand in terms of farm size shows that a very large number of farms fall within the small-size category (Table 1 & 4). However, due to the dynamics of pig farming, many of these *small* farms in the top range could reach a considerable size and become medium-scale farms upon time or conditions of production. Moreover, within medium-scale operations, larger farms are fewer than smaller ones, with the latter representing the majority of operations throughout the country. Therefore, it is clear that the analysis of data shows a scenario of pig production concentrated at medium-scale farm levels. This scenario also includes numerous farms in the small-scale category as defined by the Thai PCD (MNRE, 2005) (Table 1). This is important for the analysis of pig waste management across scales because practices reported for small farms in the DLD (2000) survey are likely to also take place when farms fall within the medium-scale farms, and viceversa. The number of farms pivoting between small and medium scales can be a high figure provided that about 80% might initially fall within the PCD small-scale category; nevertheless, taking into account the dynamics of pig production, waste production can be large.

Notwithstanding methodological limitations in exploring the scaling up of production, a logical assumption with the intensification of production yields a scenario where the number of farms decreases as the size of farm increases, shifting production to larger farms.

However this relation is not necessarily linear and production seems to concentrate in medium-scale farming levels with nonetheless small farms remaining numerous. This is important because farms in the small-farm category might actually be of considerable size and can move back and forward to the medium-scale category upon conditions of production. This means that larger small farms also need explicit environmental management because, due to waste volumes, they are not free from environmental impacts; particularly, under conditions of spatial concentration. Other sources, most likely drawing from the same data source [Department of Livestock Development] provide slightly different figures for pig production in Thailand (Pinnoi, 2007); nevertheless, the range of medium-scale farms also presents a considerable share in total production.

Therefore medium-scale farms present characteristics that make them applicable and significant to the study of the scaling up of animal production and the farmers' informal adaptations to the consequential increased environmental externalities from scaling up processes. For this purpose, farms within the medium-scale are considered symptomatic to the scaling up and intensification processes in livestock production in Thailand. Furthermore, farms within this scale operate as commercial farms and, according to Dr Naritoom (personal communication, September, 2008), most likely as family business, whether as independent producers, within cooperatives, or vertically integrated in agribusiness market chains. An interesting aspect of the relation between agribusiness, livestock production, market organization and commercial arrangements is the structure of production in terms of dominant size of operation and the management of farms as family farms. Although this thesis does not explore any further the role of agribusinesses in the development and scaling up of livestock production in Thailand, there seems to be a connection between agribusinesses and present pig production structures largely based on medium-size operations. A research exploring the existence and nature of the relationship between agribusiness and the structure of present animal production would be interesting for future research because it is likely to intertwine with the environmental dynamics of production.

2.3.3 Other Environmental Frameworks

In addition to the Pig Effluent Standards there exists a number of regulations in Thailand which could be applicable to the environmental management of pig farming. The Water Characteristics Discharged into Irrigation Systems (Royal Irrigation Department Order No. 883/2532, 1989) aims to preserve water quality in irrigation canals. In this regard, it is difficult to state if direct discharges from retention ponds to irrigation canals occur; however, it is rather possible that discharges to water bodies affect the quality of irrigation water.

On the other hand, with regard to solid waste reclamation, the Fertilisers Act of 1975 (Fertiliser Act 2518 BE) could provide an accidental but suitable ad hoc bylaw. This Act was most likely intended for the regulation of trade and addresses label specifications for chemical and organic fertilisers. It requires the labelling of chemical fertilisers to include nutrient concentration. However, for organic fertiliser, defined as a fertiliser derived from organic material (Fertiliser Act 2518 BE), the Act only requires to include the name of the organic fertiliser and the place of production, storage and sale. There is no mention about quantity of nutrients.

Although this Act was probably created to regulate exports, it reflects the uncertainty over the concentration of nutrients in manure. Nonetheless, the norm might be applicable to waste reclamation in the numerous cases where animal waste is traded.

On a different level, there are a number of policy instruments for the implementation of environmental management practices by pig farmers, such as manuals and decision tools, e.g., Decision Tree Model (PCD, 2007) or Guideline for Clean Production for Pig Farms (PCD, 2006). These materials, however, make only tangential reference to pig waste reclamation in agriculture and primarily focus on pig waste as a question of wastewater management with a considerable emphasis in biogas production.

Nonetheless, the literature review and data on pig production, as well as information collected from field visits and expert interviews, suggest that the scaling up of production in Thailand has not prevented the waste management practice of in-house solid waste separation and its purposive or consequential disposal or reclamation in agricultural fields. Moreover, the scaling up of production has augmented the environmental significance of such practices, however, they largely remains an informal practice with formal environmental policies focusing on wastewater.

2.4 Summary of Expert Interviews

The present section summarizes group meetings and expert interviews conducted as part of the field work. The interviews were semi-structured around one topic: the use of pig manure in agriculture as a form of animal waste management.

Some expert interviews were conducted during group meetings which had not been arranged for the purpose of this thesis. In this case, the interviewer specifically addressed the interviewee with regard to the topic of environmental management in pig farms. All interviewees, except those in group meetings, were provided with a written summary of the research. This allowed an open-ended interview because interviewees knew the research topic and research questions. In most cases the interviewees provided some materials such as articles, manuals or reports and provided information in relation to the materials.

Expert interviews and field visits allowed the researcher to construct an outlook of the environmental dynamics in pig farming in Thailand by considering both the actual environmental dynamics and the environmental culture dominant among experts working in fields related to pig waste management. This outlook was used to analyse the significance of pig solid waste reclamation in the overall dynamics. Fieldwork through expert interviews and field visits complemented the examination of data and literature allowing an analysis embracing present pig production and policy situation. Fieldwork confirmed waste management practices and allowed the researcher to look into the reasons behind current environmental frameworks and how these reasons relate to present environmental dynamics of production.

The use of data obtained from the interviews is however limited because, in the opinion of the researcher, initial views by most interviewees were that a regulatory approach to solid waste use in agriculture was hardly attainable. However, this regulatory approach was precisely the topic of the interview but for reasons this thesis identifies as *environmental culture*, it was difficult to redirect interviews away from projects and benefits of biogas technology for pig waste treatment. This made very elusive addressing the possibility of turning traditional practices into policies by their integration within present environmental frameworks.

In line with Dalgaard's et al. (2003) discussion on agroecology as a field of study, there was a considerable array of disciplines among experts. This array made difficult to define a common denominator for an integrated view among the interviewees with regard to pig solid waste reclamation. Moreover, experts were polarized, with animal nutritionists on one side [leaning towards feed as pollution control method] and experts on biogas on the other. Indeed, it seems like animal scientists, including veterinaries, are active in the field of livestock environmental management. This is interesting because it might create a synergy in supporting or favouring certain waste management practices or the overlook of others. Naturally, each expert had a view rather restricted to their respective expertise and current projects. Attempts were made to include experts from land management but there were few available and not directly working on the topic. Given the number and diversity of technical disciplines and agencies affecting or affected by the practice of pig solid waste reclamation in agriculture, this thesis suggests looking at waste reclamation by using actor analysis techniques (Hermans & Thissen, 2009), yet such techniques will not be further develop in this thesis.

Getting in more detail into the interviews, a group meeting with Dr Blanco in October 2007 in an experimental biogas plant near Cambridge, England, serves as evidence of the difference between using anaerobic digestion technology for obtaining biogas or for animal waste treatment. In the case discussed with Dr Blanco, the experimental biogas plant was considering rejecting animal waste in favour of other products with more constant, higher biological oxygen demand (BOD) and higher gas yields. Likewise, it was helpful to learn how, according to legislative demands in England, residues from the biogas process need to be sanitised (usually this means pasteurized) before they can be released to the environment, including their use in agricultural fields.

Dr Noppadol Kongsricharoern (personal communication, September, 2008), an expert in pig waste management and Director of the Thai Environmental and Energy Development Ltd. (TEED) is also in charge of farmers group meetings and progress reports under the Livestock Waste Management in East Asia project (LWMEA). TEED basically focuses on the implementation of biogas technology for pig waste management and Dr Kongsricharoern was very supportive of anaerobic digestion for biogas production, but also for animal waste treatment. Dr Kongsricharoern believed that the problem caused by pig solid waste would be reduced because anaerobic digestion reduces the amount of waste and waste can still be used in agriculture. Dr Kongsricharoern acknowledged that sanitising waste (digestate) from anaerobic digestion would be very difficult since cost of biogas technology was already the main constrain for its implementation by pig farmers. Moreover, Dr Kongsricharoern also commented that planning the integration of pig waste agricultural reclamation into policies would involve a large number of agencies, This would make policy processes rather complex and, therefore, biogas as in-farm waste management was a faster and clearer option. This interview showed that there can be two different views in the implementation of biogas technology in animal farming, one view focusing on waste treatment, e.g., PCD (2007) Decision Tree Model for Swine Farms, and another view focusing on energy generation. Although, theoretically, they complement each other, in practice, this does not seem to happen, because according to Kiratikarnkul (2008) over 80% of in-farm biogas production is lost.

Dr Arux Chaiyakul of the Department of Livestock Development, Ministry of Agriculture and Cooperatives (DLD) and Mr Sommai Chatsanguthai, expert in biogas technology and DLD Consultant for the Livestock Waste Management in East Asia Project were interviewed in September 2008. Dr Chaiyakul confirmed the institutional emphasis on the implementation of biogas technologies in pig waste management. However, Dr Chaiyakul recognised the importance of pig waste agricultural reclamation and showed great interest in hearing how other countries had approached the regulation of pig waste reclamation. Nevertheless, Dr Chaiyakul acknowledged the great difficulties of setting standards for agricultural use of pig waste. In relation to Dr Kongsricharoern's comments on the large number of agencies that the formalization of waste reclamation would involve, it is important to notice here that the Department of Livestock Development focuses in the animal farm as a unit. Another important issue, commented by Dr Chaiyakul, is the use of pig waste in freshwater fish farming. Dr Chaiyakul confirmed that the use of raw manure as feedstuff in freshwater fish farming is frown upon the Department of Livestock Development. They also acknowledge that manure could eventually accumulate for long time in farms before it is taken away.

Another interviewee was Dr Charan Chantalakhana (personal communication, July, 2008), retired Animal Nutritionist, former Director of Suwanvajokkasikit Animal Research and Development Institute at Kasetsart University (KU) and with more than three decades of experience in livestock production and development in Thailand. Although his expertise is not pig production, Dr Chantalakhana interview provided great information for the understanding of how animal production had changed from traditional farming to modern intensive operations.

Dr Piya Duangpatra (personal ccommunication, August, 2008), Soil Scientist and Professor at the Interdisciplinary Program on Sustainable Land Use and Natural Resources Management at Kasetsart University, informed on the multiple practices in manure use in agriculture and how the agronomic and environmental functioning of these practices is rather unknown. Two very important points were, first, that farmers might use pig solid waste as fertiliser and soil amendment in addition to chemical fertiliser and, therefore, when used as soil amendment, manure nutrients might not be taken into account; and, second, that the use of manure by agricultural farmers might depend on the season. For instance, in some fields, rice farmers might use manure during the season when they do not grow rice and, instead, they grow other crops, onion for instance. This adds to the complexity of assessing agricultural practices of waste reclamation. Dr Piya also highlighted that manure use by rice farmers often takes place just before fields are ploughed. In paddy rice this means that fields are likely to have waterlogged soils. Finally, Dr Piya mentioned about literature in Thai language that addresses pig wastewater fertilisation practices and pointed out that it was not straightforward to discern the nature of improvement in production when higher yields were claimed. As addressed elsewhere in this thesis, most likely, the difficulty in discerning any clear causality is due to the irrigation factor associated with this fertirrigation practice. Dr Duangpatra also commented that it was generally accepted that transportation costs are a limiting factor in the use of manure in agriculture.

Dr Uthai Kanto (personal communication, September, 2008), Animal Nutritionist, Professor and Director of Suwanvajokkasikit Animal Research and Development Institute (KU), explained that one barrier for manure use in agriculture is that it is more difficult to transport and manage than other options. Some pig farmers with agricultural land sometimes might use manure just because it is readily available, but they might still conduct other fertilisation practices as well. As Dr Kanto commented, there is indeed a diversity of practices in managing manure, including for instance the addition of byproducts from the cassava processing industry for allegedly added fertilising effects, or crop irrigation with lagoon effluents. Dr Kanto commented on Pig Manure Extract, a fertiliser produced by soaking pig manure in water and applying this water to plants.[5] Another important aspect Dr Kanto addressed was the use of especially designed diets for pig feeding to reduce the amount of phosphorus excreted. There is actually a considerable corpus of literature on this question briefly cited elsewhere in this thesis without further development. Conclusively, the information obtained from the interview to Dr Kanto shows how practices in agriculture and waste reclamation might be quite diverse and even unpredictable.

Dr Pierre Gerber (personal communication, August, 2008; 2010), Livestock Policy Officer, Food and Agriculture Organization of the United Nations, provided a copy of the nutrient model *STRAW (*2010), or Support for the Treatment and Recycling of Animal Waste, a software which reflects the interest by international programs on the spatial distribution of

[5] *Additional information on Pig Manure Extract is provided in section 2.3.*

livestock and, therefore, not only on a focus on biogas technology but also on the reclamation of waste as a resource in agriculture. STRAW has been developed to support livestock producers in the waste management of the farms. For that reason, this thesis interprets STRAW as an in-farm environmental management instrument. This might affect how STRAW, and nutrient models in general, operate in the environmental dynamics of animal production.

Ms Sunee Thapinta and Dr Wimalin Klaewtanong (personal communication, August, 2008), officials from the Division of Water Quality, Pollution Control Department, Ministry of Natural Resources and Environment (MNRE), provided substantial information on the Decision Tree Model designed for livestock farmers to decide on the environmental technology for their farms. They also explained how the use of animal waste in freshwater fish farming is very likely to be associated with pollution caused by effluents from freshwater fish farms, where the use of waste as feeding hardly follows specific nutrient plans. Ms Thapinta and Dr Klaewtanong were open but sceptical on the possibility of developing scientifically viable legal standards for the use of pig solid waste in agriculture because of considerable diversity in biogeophysical conditions across the country and the variability in the spatial distribution of animal farms and agricultural land.

Mr Chingchai Lohawatanakull (personal communication, September 2010), Vice chairman and Director of Charoen Pokphand Group Co., Ltd. (CP), briefly explained the diversity of possible arrangements between producers and the CP group, as well as CP contribution to economic development by the development of animal production from traditional farming. Mr Lohawatanakull also addressed the presence of the CP group in Europe and Vietnam, in Europe regarding sales of meat products from Southeast Asia and in Vietnam in relation to CP’s involvement in animal farming.

Dr Naritoom (personal communication, September, 2008), Sociologist at Kasetsart University, explained how urban development has been displacing animal farms away from areas near main roads and the proximity to Bangkok Metropolitan. She also addressed that sometimes it could be rather difficult to address certain topics with pig farmers. One very interesting piece of information provided was with regard to environmental management and farming arrangements with corporations. Agribusinesses provide advice on environmental management to pig farmers (this was later confirmed in interview to pig farmers during field work in Field site 3 in Yasoton province). However, according to Dr Naritoom, this might cause compliance agencies to overlook farms under agreements with agribusinesses groups because these farms are considered as already receiving environmental guidance from such groups.

Dr Chongrak Polpraset (personal communication, August, 2008), Professor, waste management expert, School of Environment, Resources and Development, Asian Institute of Technology, explained that there is a considerable demand for pig manure by freshwater fish farmers. However, unlike in Europe, the use of pig slurry in agriculture in Thailand is rather uncommon. When pig slurry is used, it usually takes place in fields nearby the animal farms since handling and transportation of slurry requires machinery and farms rarely have the appropriate equipment. In those cases where it takes place, it is usually by flooding method since systems such as injection have not been implemented in Thailand.

Dr Schaffner (personal communication, June, 2010) is the author of *Modelling the contribution of pig farming to pollution of the Thachin River. Clean Technologies and Environmental Policy, 12(4), 407-425.* (Schaffner et al., 2010). The nature of this communication was to clarify on what basis Schaffner's model accounts for the use of pig solid waste as efficiently used. This question is further developed later in the text.

Dr Wijarn Simachaya, (personal communication, August, 2008), at the moment of the interview Officer at the Air Pollution and Odour Control Division, formally working at the Water Quality Division, both in the Pollution Control Department, MNRE, explained that there was a project for the development of a *Compliance Assistance Centre* [to support pig farms adhering to effluents standards] (Simachaya, 2008). He recognised [referring to the time he worked at the Water Quality Division] that most efforts were mainly directed to improving farms compliance with effluents standards. Dr Simachaya agreed that there is a risk of diffuse pollution from pig solid waste reclamation from nutrient surpluses in agriculture and that it contributes to the overall levels of pollution in rivers. Indeed, he added, the issue of diffuse pollution was starting to attract interest from officials. However, it was already difficult to address point pollution and, therefore, it had been a priority. The results from this pollution abatement strategy were expected to be positive, although Dr Simachaya was clear that there are other factors controlling the capacity of pig farmers to prevent pollution. One additional measure to address these other factors consisted in strategies based on cooperation and collaboration among groups in areas affected by pollution.

Dr Pornsri Suthanaruk and Dr Warapong Tungittiplakorn (personal communication, August, 2008), both Officials from the Environmental Quality Division, Pollution Control Department, MNRE, expressed their interest in the development of a system and standards to control diffuse pollution from pig waste use in agriculture. However, they also expressed that beyond its development lays the challenge of implementation. They explained how difficult it is already to address and assess if farms were complying with effluent standards. For instance, one important setback was the question on when and where to sample. They also explained that small farms (as defined by the PCD category) are not obliged to comply with effluent standards.

3. DISCUSSION

What is clear from Thailand is the following: first, pig farming in Thailand has experienced a transformation in scale and in production systems. Pig production has undergone a 1.5-fold increase from 1978 to 2008, but more importantly, this has been accompanied by a scaling up in the average size of farms with a growth from few heads in backyard farms and only 4% of farms with over 110 heads in 1978, as reported by Falvey (2000), to approximately[6] 30% of fattening farms with over 500 animals and 12% of breeding farms with over 50 sows, based on DLD (2006) data (Table 1) or, as calculated from data reported by the Pig Magazine (2004), about 16% of all farms with over 50 animals and about 4% over 500. As addressed in section 2.1.1, a cross-analysis of data with national pig production reveals a scaling up of production structure to comparatively large operations. Second, as addressed through out this thesis, there is evidence that the environmental management implications of this transformation are considerable and yet poorly understood. Third, environmental governance in face of this transformation would seem to be weak. Finally, the role played by informal practices rooted in traditional waste management is also largely overlooked.

The projection of waste reclamation systems from smaller to larger scales cannot be understood as a direct one along a scaling up to larger scales of production in both absolute terms (total production) and in terms of farm size and geographical clustering of production. Under new scales of production it is of great significance that the role of agricultural reclamation of pig solid waste implies two levels, one at animal farm level and the other, beyond the animal farm, at agricultural field or fish farm level.

3.1 Beyond the Animal Farm

At animal farm level, an on-site [in-farm] environmental management is defined by practices conducted by farmers. On the other hand, beyond the animal farm, at aquaculture farm or agricultural field level, this thesis identifies an off-site environmental management of pig waste defined by practices conducted by agricultural or aquaculture farmers. At the same time, agricultural geography at a given geographical region, delineated by physical or human geography, sets forth conditions affecting the environmental management, dynamics and significance of pig solid waste in agriculture and aquaculture.

[6] *Calculated as indicative only (see Table 1) based on data from the Department of Livestock Development in 2006 (DLD, 2006) and which exclude farms below 50 piglets / 10 sows.*

In effect, as a result of the scaling up and specialization of production and the environmental dynamics of pig production, practices defined as off-site management are conducted by different social actors from livestock farmers. These actors are agricultural and aquaculture farmers collecting manure from pig farms. Consequently, the situation unfolds in that waste reclamation does not depend only on livestock farming, but on agricultural and aquaculture farming conducted in locations away from animal farms and, therefore, affected by conditions off-site the animal farm. The significance of off-site management remains contingent to in-farm waste management and its relative location; however, it is also contingent to the relative location where off-site management takes place. In this context, the scaling up of production has transformed the significance of waste separation and reclamation practices and, as this thesis points out, caused off-site waste management to become critical to the environmental dynamics of pig farming. This way, the environmental dynamics of pig farming reach beyond the animal farm to the agricultural and aquaculture field level.

The scaling up of pig production, with agricultural and aquaculture reclamation of solid waste as purposive or consequential to waste management practices, has extended the environmental significance of waste reclamation as a tacit and indispensable option for pig farmers. However, for waste reclamation to function as a positive environmental management practice, it has to scale up in terms of environmental performance to match production scenarios because agricultural or aquaculture use of manure is not exempt of environmental impacts.

Aside from benefits to agricultural and aquaculture farmers as well as potential environmental impacts from off-site practices, for the pig farmer, waste reclamation is highly significant because the removal of solid waste from the farm greatly supports the farm environmental viability. However, assessing the environmental significance of agricultural and aquaculture reclamation as off-site environmental management is a complex task precisely because, as a result of the scaling up of production, it reaches beyond the animal farm and does not only depend on livestock farmers. Due to the nature of the connection from one-site to off-site, environmental ramifications are highly related to the geographical fabric of animal and agricultural farming. Over how they connect and the geographical fabric pivots the environmental significance of reclamation practices, then translating into positive or negative environmental effects.

The distinction between positive and negative environmental effects can be ambiguous because of the complexity and uncertainties surrounding off-site waste treatment. At animal farm level, pollution from solid waste [manure] might be mainly from run off (Photo

8 & 9); however, at off-site level, beyond benefits deriving from animal waste reclamation, there is a widespread possibility of diffuse pollution from manure misuse in agriculture or aquaculture. As addressed elsewhere in the text, manure use in agriculture is also associated with negative effects or disservices not only from nutrient surpluses but also from other sources, such as heavy metal accumulation in soils, soil salinisation, pharmaceutical residues or biological risk from pathogens. These disservices of manure use in agriculture are moderated by variables set forth by the biophysical environment and agriculture geography, variables such as agricultural land availability, land use and environmental policies defining the environmental geography of pig solid waste reclamation.

Therefore, although these variables depend on to the environmental dynamics at in-farm level, with the scaling up of production, the environmental significance of such dynamics depends deeply on conditions beyond in-farm level to reach regional livestock and agriculture geography levels. This way, livestock and agriculture geography become paramount to the environmental significance of off-site management. Nonetheless, off-site environmental management can affect the environmental conditions at individual animal farm level by negative feedback processes. For instance, if a new pig farm opens, an already established farm conducting waste separation might find that waste accumulates for a longer period of time. Moreover, new farms do not have to be pig farms because agricultural farmers might prefer manure from different livestock instead of pig manure (Gerber & Menzi, 2006). Accordingly, local and regional pig farming densities and structures of production in terms of farm size affect the performance of pig solid waste reclamation and, therefore, the environmental dynamics of pig production. What is more, the geographical distribution of other livestock might also affect the environmental dynamics of pig production. Additional factors might include those derived from governance and public perception on the safety of manure use (Burton, 2009) and acceptance by communities.

Notwithstanding the agricultural value of pig waste, possible disservices in the form of environmental impacts means that, although reclamation by agricultural and aquaculture farmers represents in many cases a substantial part of the integral pig farm waste management, its interpretation as off-site management is not exempt of questions over its environmental performance and its role in the environmental dynamics of pig farming.

This thesis supports the integration of agricultural reclamation of pig solid waste into policies by defining on-site as in-farm waste management and recognising the management level beyond the animal farm as off-site waste treatment. Off-site management takes place away from pig farms but is critical for complementing on-site waste treatment. At higher geographical levels from the individual pig farm, off-site management is framed by the absolute and relative availability of suitable agricultural land in relation to pig farming [and other livestock] scales of production; absolute in terms of total figures and relative because additional variables and conditions mediate practices in pig solid waste reclamation: variables and conditions which dictate the performance and environmental dynamics of off-site waste management.

In this context, a key element in the environmental dynamics of pig production is the transfer of the environmental management between on-site and off-site management. This transfer represent the connection between livestock and agricultural geography. One way this connection is presently taking place is through trade. This trade means a transfer of waste as a marketable good and implies a change of actors in the environmental dynamics of manure as an agricultural resource. Since waste is transferred to agricultural farmers, the environmental dynamics are likely to be affected by the typology, location and distribution of agricultural farms. Therefore, agricultural farmers are decisive in the functioning and significance of agricultural reclamation as off-site waste management. In this fashion, in-house separation practices and the purposive or consequential reclamation of pig solid waste can be interpreted as a market-based solution to the pig farm environmental management. Indeed, revenue from the trade of manure by pig farmers can discourage them from implementing and investing on biogas technology as a waste management option (Burton, 2009). However, Dr Kongsricharoern in personal communication in September 2008 suggested that digestate from biogas technology reaches a higher price than common pig manure. On the other hand, Dr Polpraset (personal communication, August, 2008) reported very high profits from manure sales by pig farmers to freshwater fish farmers. Indeed, as previously mentioned in this thesis in the case of Vietnam, Vu et al. (2007) reports on farmers keeping pigs only for the value of manure as freshwater fish feed.

This thesis shows that practices rooted in traditional use of manure in agriculture are being projected in the scaling up of production at levels beyond the pig farm. Moreover this projection is taking place despite the fact that environmental frameworks do not explicitly include such practices and essentially focus on in-farm wastewater management and biogas technological solutions.

The reason for this *no inclusion* seems to be rooted in institutional support to biogas in what seems to be a general understanding of biogas technology as positive and beneficial in practically all possible ways. Moreover, focusing on biogas technology seems to prevent from having to deal with the sensitive question of fresh manure. The outcome is that environmental frameworks overlook present solid waste reclamation practices. Indeed, it would be difficult to imagine a pig production scenario in Thailand with no agricultural reclamation of solid waste as part of its environmental dynamics. Nonetheless, the practice largely remains an informal one, with formal practices addressing pig waste management as a question of wastewater.

In conclusion, the scaling up of pig farming has led to a scenario where informal pig solid waste agricultural reclamation has become of great significance to the environmental dynamics of pig production even beyond the animal farm level. Convincingly, the environmental dynamics and performance of waste reclamation as off-site environmental management need to be considered at two geographical levels. One is at the reclamation site level. Another one is at larger scales in relation to policy and agroecological levels defined by natural and human geographic boundaries.

3.2 Environmental Significance of Informal Management Practices

This thesis highlights that formal environmental management of pig farms focuses on pig waste as a question of on-site and wastewater management. Although on-site management is obviously necessary, this thesis puts forward that off-site waste management is also an essential part of the environmental dynamics of pig farming. Therefore, environmental frameworks grounded only in management of wastewater at in-farm level offer a limited overview over the full environmental dynamics of pig production. The best case scenario is in this case a hypothetical full compliance with effluents standards. On the other hand, fieldwork shows that, perhaps because it is rooted in traditional use of manure in agriculture, reclamation is understood as taking place at in-farm locales. However, it is not clear if this is always the case.

Certainly, actual environmental dynamics show that compliance with effluents standards alone would not solve the pollution threat from pig farming. Apart from the challenge of controlling effluents on farm-by-farm basis as mentioned earlier in the text, in areas with high density of pig farms there can be combined effects of effluents from several farms. It is not clear how current effluent standards account for this possible effect. In this regard, it is noticeable that effluent standards for larger farms (Standard B, Table 3) are actually less restrictive than for medium-farms. It is unclear the reason why, although it might be related to an anticipation to possible concentration of medium-scale farms in high pig production areas where the combined effects affect the same water body (Photo 1). Nonetheless, the standards theoretically apply to a farm level as the unit of management.

In a model analysing the contribution of pig farming to pollution in the Thachin River (Schaffner et al., 2010), a water body [west of Bangkok] affected by a high pig production area [northwest of Bangkok], the author indicates that not only the treatment but also the recycling of waste is important in the control of pollution from pig farming. This statement in Schaffner et al. (2010), however, refers to the recycling of wastewater. With regard to solid waste, the model considers pollution from manure at in-farm solid waste management (Schaffner et al., 2010) reporting manure use in agriculture as "*efficiently reused*", an account based on expert knowledge as confirmed with Dr Schaffner in personal communication, June, 2010.

Pig waste reclamation is therefore considered by experts as efficiently used as a resource in agriculture and, arguably, does not contribute to the environmental impacts of pig production. Accordingly, it could be interpreted as an efficient form of waste management. From the point of view of waste management, and using only nitrogen as indicator for explanation purposes, solid waste separation should not necessarily be discouraged because, according to Tuan et al. (2006), pig solid waste[7] presents higher concentration of nitrogen than pig wastewater[7, 8]. The perception of efficient use of solid waste is agriculture is therefore decisive in the environmental dynamics of pig production. If waste is efficiently used, it means that there is a good match between pig solid waste production and demand by agricultural and aquaculture farmers in terms of absolute amounts and in terms of geographical distribution. Moreover, under this assumption, agricultural and aquaculture use of pig solid waste carries no substantial disservices. If this is the case, waste reclamation is a well-suited waste management alternative and should be formally recognised at policy level.

Notwithstanding the importance of compliance with effluents, this description intends to point out that a focus on effluent standards under present production scenarios might deflect an alternative waste management. With no official recognition of the significance of separation and reclamation practices, there could be farms where, whether for lack of demand or no official recognition, after separation, subsequent off-site management is not observed or poorly taken care of. First, this might result in higher polluting effluents; second, in poor in-farm management of solids, fast sediments build up in ponds and poor management, disposal or agricultural reclamation of solid waste and sediments.

[7] *Collected prior mixing with water.*

[8] *It is difficult to assert which phase, solid or liquid from slurry has a higher content in nitrogen, and therefore higher value as fertiliser and polluting capacity. Most studies available refer to solid and liquid from slurry (post-mixed), see for instance Sanchez & Gonzalez (2005).*

The observance of the actual dynamics in the environmental management of pig farms allows a blueprint for waste management in a two-phase and two-way system. First, from the differentiation of wastewater and solid waste; second, from the differentiation of in-farm [on-site] and off-farm [off-site] waste management. Wastewater is treated on-site in the animal farms whereas solid waste is stabilised on-site and then managed or treated off-site through reclamation in agriculture [or aquaculture].

On the other hand, however, the recycling of manure in agriculture is not a straightforward practice. Leaving aquaculture aside and focusing on agriculture for simplification purposes, multiple variables limit the environmental performance of agricultural reclamation as an off-site waste management practice. To begin with, the environmental significance of agricultural land in a pig farm is going to depend on whether there is agricultural use of waste or, rather, agricultural land is used for waste disposal. Claims of agricultural reclamation of waste can hide waste disposal practices if there is poor or no removal of manure by agricultural farmers. This might well happen under certain geographical scenarios such as high density of pig farms and low availability of agricultural land. It could also happen, for instance, for social reasons, in areas where population rejects the use of pig manure in agriculture.

Fieldwork revealed one case rooted in the social sphere as limiting factor in the environmental functioning of pig solid waste reclamation. The owner of a rubber plantation had been given, free of charge, a large amount of semi-dried pig waste. The rubber farmer thought he needed the waste because he believed that chemical fertilisers were of poor quality, apparently, a growing concern among farmers in Thailand. The removal of waste was of great help for the pig farmer but the rubber farmer actually stated that he did not know how to use the manure. Finally, he had used it along with chemical fertilisers of dubious quality. The line between reclamation and disposal is in this case a thin one.

Moreover, this example also shows that, in addition to agricultural land availability *per se*, there is a question of agricultural farmer practices. Armstrong et al. (2007) studied practices in reducing nitrogen and phosphorous losses in runoff at manure application and noted that agricultural practices by farmers are critical in all stages of animal waste reclamation, from collection to application. In a case study by Bosch et al. (1995) in Nebraska, USA, government recommendations to conduct nitrogen testing did not always lead to adjustments in fertiliser application. Bosch et al. (1995) therefore reported that agricultural practices and nutrients management do not necessarily follow scientific recommendations. Adjustments by farmers in the use of animal waste as fertiliser or soil conditioner are, therefore, expected to be common practice and in accord to their perceptions. For instance, Wijnhoud (2007) reported on farmers in Thailand modifying nutrient inputs according to their estimations of wastewater inflow to fields.

On a related note, in relation to government fertiliser recommendations and farmers' practices, in a study in Northeast Thailand, Rigg (1985) reported that government recommendations were seen as too simple for the complex decision systems. Farmers' practices were based on complex relations including social factors (Rigg, 1985). One example is how farmers views on the limitation of the environment in providing high agricultural outputs could prevent them from using more chemical fertilisers (Ibid). In terms of manure, collection and labour cost precluded manure use (Ibid).It is therefore important to consider that waste reclamation is subjected to a high degree of self-regulation by agricultural farmers, especially given the complexities surrounding manure use and the uncertainty in the concentration of nutrients (Schröder, 2005), particularly if compared to chemical fertilisers.

Nutrient models aid farmers with the question of how much manure they can use, often, as in the case of STRAW, this is based on a given crop. Models also provide a waste management tool to support farmers achieving a positive environmental performance for animal waste reclamation in agriculture. Models such as STRAW estimate the amount of waste suitable for a given plot of land under diverse scenarios for animal farms and crops. This way, nutrient models contribute to bridge the gap between animal farms and agricultural fields.

Modelling nutrient budgets and flows connect livestock production and agriculture at farm-field level taking into account the quantity and quality of manure and certain conditions at agricultural field level (e.g., crop). Moreover, such models can include biogeophysical conditions at agricultural field level. However, as addressed earlier in this text, the theoretical approach in which nutrients produced at animal farms match their use in agriculture under balanced budgets is averted by the fact that waste reclamation might be conducted by a different actor and with his own diverse practices. Beyond agricultural practices at field level, such as manure application timing, constraints include the allocation of agricultural land by agricultural farmers and other mutually interrelated geographical factors such as land use and soil type, urban development, or dominant crops in a given area. Overall, these models reflect the fact that positive environmental performance at agricultural level is contingent to in-farm as well as field level conditions and practices.

Therefore, one significant element to consider in the implementation of models such as STRAW is the fact that waste reclamation is often conducted by agricultural farmers, not animal farmers. Animal farmers benefit from the removal of waste from the farm and the associated revenue from manure trade. While a pig farmer may or may not interpret waste reclamation as off-site waste management, an agricultural farmer is not likely to bear the cost of manure, transportation and labour to proceed with the environmental management of pig waste. The use of manure by agricultural or aquaculture farmers is, naturally, not understood as waste management but as utilization of an agricultural resource. Therefore, the motivation and determinants for manure use by agricultural farmers differ from those for animal farmers. Agricultural or aquaculture farmers often pay for and are interested in certain characteristics of manure which they believe would benefit their economic activities. This also means, however, that if, for instance, agricultural farmers consider the use of manure based only on nitrogen concentrations, disservices from other qualities of manure, as those described earlier in text, might occur. It could be argued that agricultural farmers might not initially be subjected to excessive use of organic fertiliser if we consider that they pay for it. However, this is not necessarily factual because, for instance, when manure is used as soil amendment, chemical fertilisers might also be used, adjusting or not for quantity and timing in application rates.

From the perspective of the environmental dynamics of pig production, nutrient models (e.g., STRAW) support the direct integration of animal farming in the broader agricultural production by providing an estimate of the extension of land needed for a positive environmental performance at field level. In this sense and in absolute terms, the dependency of pig production on land corresponds with Park et al. (2006), who views land availability as the global geographical factor in the distribution of pig production. This can be interpreted as that, in theory, governing livestock is affected by the environmental significance of waste reclamation practices in agriculture, so much as to determine the location and distribution of production.

At any rate, in the scaling up of production, there is the question of how aquaculture and agricultural waste reclamation works in parallel with animal production when both are contingent to complex organizational and geographical dynamics with regard to their spatial distribution, structure and scales of production. One way to address this question is by looking at the waste transfer process from animal farmers to agricultural [and aquaculture] farmers. This transfer represents the intersection of spatial and scale levels between agricultural and livestock geography. Policies can condition this connection by setting and drawing boundaries at higher geographic hierarchical levels. One such level would be legal standards for how manure is treated or sold.

Several experts interviewed, Dr Symachaya (personal communication, August, 2008), Ms Thapinta (personal communication, August, 2008) and Dr Klaewtanong (personal communication, September, 2008) agreed that setting application standards to regulate the use of manure in agriculture by the application of environmental or agronomic thresholds is not likely to change the situation on how such practices are taking place and neither would standards be welcomed by agricultural and animal farmers.

The case of the United Kingdom (UK) and European Union over regulations on nitrogen in animal waste use in agriculture (Nitrates Directive 91/676/EEC) provides an example of land-based application standards. This policy limits the amount of organic fertiliser[9] in agricultural fields, whether for manure use as fertiliser or soil amendment, and as waste management practice or else. To support farmers and put the Directive into practice, the UK provides farmers with the nutrient model MANNER (MANNER, 2000). The use of MANNER represents an example in which nutrient budgets could theoretically determine maximum livestock densities in a given geographical area and, therefore, act as a policy instrument for the spatial distribution of animal farms. This would however be contentious because of the limitations that this type of policy [spatial distribution on environmental basis] would impose to economic development, particularly in developing countries. Moreover, in the root of this contention there are scientific uncertainties in the use of environmental thresholds for agricultural reclamation of animal waste. Indeed, as seen earlier in the text, the United Kingdom supports research to validate a higher application rate (DEFRA, 2007) than that established by the EU (Nitrates Directive 91/676/EEC, 2000).

On the other hand, the use of models for this purpose would contrast with an alternative approach drawn from Chambers et al. (2008) over setting application standards based on what somewhat underlines the uncertainties in the above-mentioned environmental criteria. This is, different ecosystems react differently to the level of nutrient concentrations. Chambers et al. (2008) suggest the observance of ecosystems' good ecological conditions by looking at target concentrations. This can be interpreted as that, instead of setting standards at plot or field level where pollution originates, environmental monitoring can focus at the ecological level by means of the ecosystem resilience. This provides an example of waste use in agriculture addressed as a function of the agro-ecosystem remediation capacity in line with Newton et al. (2003). Therefore, such option

[9] *Organic fertiliser interpreted as from animal origin.*

includes the possibility of higher concentration as legal standards than those based on plant nutrient demands.

Furthermore, any sort of regulation or recommendation [independently from animal farming] related to nitrogen or phosphorus in agriculture could affect the reclamation of animal waste in agriculture. For instance, recommendations on the use of chemical fertilisers or changes in their market price could alter the functioning of pig solid waste as off-site waste management for the livestock farm.

This section shows that the scaling up of production highlights the environmental significance of pig solid waste reclamation in the agroecology realm; however, there is a need to explore specific levels of waste reclamation within and beyond the livestock farm and at agricultural field level. Furthermore, a major challenge is how to incorporate informal practices into environmental policies, particularly, when practices might not correspond with the present environmental culture in institutions and experts that are likely to influence prospective environmental frameworks. This is addressed in the next section.

3.3 Environmental Culture and Waste Reclamation

Based on the notion of *ecological culture* by Escobar (1996), this thesis construes as institutional *environmental culture* the prevalent focus on the benefits of biogas technology for the environmental management of pig production identified in interviews and materials consulted. This institutional *environmental culture* reflects what Ludwig (2001) defines as *technological fix*, or a recourse to technological innovation in the development of policies (Ibid). This thesis suggests that this institutional culture accidentally or inadvertently deflects the development of alternative waste management options despite their existence and significance to the environmental dynamics of pig production.

This institutional environmental culture is found to agree with Vanloqueren & Baret's (2009) framing of the institutional support to biotechnology against agroecology innovation with the organizational, social and policy processes construing a *technological regime* in agriculture science and technology. According to Vanloqueren & Baret (2009), while international assessments and reports on agriculture science and technology recommend an agenda based on agroecology, factors that influence research choices within agricultural research systems (e.g., funding priorities and scientists' cultural routines) result in a paradigm of technological dominance that sets aside agroecology.

In view of that, this thesis indentifies an environmental culture following a technological regime which relegates waste separation and reclamation practices. Reclamation practices are acknowledged, not rejected but neither regulated nor supported. The situation is a *status quo* where most interviewees were aware of waste reclamation but could hardly comment on it and its development or regulation; instead, attention was often drawn to biogas technology as waste management alternative. For the majority of interviewees, the complexity and uncertainties surrounding waste reclamation made the agri-environmental question subsidiary to biogas technology. Experts at the Pollution Control Department were the most responsive to the hypothetical idea of developing some sort of standards addressing waste reclamation in agriculture.

According to Dr Kongsricharoern (personal communication, September, 2008), biogas technology is a common waste management alternative in pig farming in Thailand and its implementation in the last years has substantially increased. Indeed, the survey conducted in Thailand by Kiratikarnkul in 2008 reports that about 30% of pig farms surveyed used biogas technology for waste management. However, only 1% of biogas produced was used for heating and cooling and around 83% was lost. In fact, as noted by Dr Blanco (personal communication, October, 2007), exploitation of biogas systems for energy production require consistent biogas yields and other feeds can provide more reliable and higher yields than pig waste.

On the other hand, notwithstanding the benefits of biogas technology in pig waste management, anaerobic digestion byproducts high in nutrients (biosolids or digestate) need further environmental management and are commonly disposed or used [reclaimed] in agriculture. Therefore, digestate also accounts as solid waste treatment. In this regard, an issue uncovered by Dr Blanco (personal communication, October, 2007) is that, in the case of England, digestate from animal waste needs to be sanitized [pasteurized] before it can be used in agriculture. However, according to Dr Kongsricharoern (personal communication, September, 2008) this will be an impossible demand in Thailand, where investment costs already hinder the technology implementation.

The complexity of keeping consistent biogas yields was confirmed in a group interview and field visit to a pig farm in Ratchaburi, a province within the proximity of Bangkok. This farm had implemented biogas technology, but was supplementing pig waste with glycerol[10] to achieve *more energy* [as defined by the farmer] from the anaerobic digestion of pig waste. Although this farmer in particular had done a substantial investment in biogas technology, Kiratikarnkul (2008) states that despite government financial aid,[11]

[10] *Glycerol was reported to be available for free from the Diesel production industry, farmers have to pay for transportation cost.*
[11] *Government financial aid could cover up to 38% of the cost (Kiratikarnkul, 2008).*

high investment cost and ineffective use of the biogas drives farmers to other waste management alternatives. Moreover, as Burton (2006) reports, available manure trade provides a readily income which contributes to farmers not having to engage and invest on biogas technology. In the above-mentioned example, the farmer also prepared pig solid waste for its reclamation in agriculture (Photo 10); therefore, the implementation of biogas technology does not necessarily prevent the reclamation of pig solid waste.

As noted, the gearing towards implementation of biogas technology identified in expert interviews is recognised as an institutional culture in a similar manner to the technological regime outlined by Vanloqueren & Baret (2009). This is symbolized by financial support, as illustrated in Kiratikarnkul (2008), and by materials distributed by the Pollution Control Department, such as the Decision Tree Model for Pig Waste Management (PCD, 2007), a model for the selection of suitable anaerobic digestion technologies according to farm characteristics.

An additional sign suggesting this technological regime can be drawn from the cost-benefit analysis of waste management alternatives conducted by Kiratikarnkul's (2008). As noted earlier in the text, although Kiratikarnkul (2008) includes *organic fertiliser* [waste reclamation] as waste management alternative, the study, however, pays special attention to biogas technology because, it states, there is strong promotion of biogas technology by the government. A projection of Kiratikarnkul's (2008) beyond intrinsic scientific reductionism would benefit from an integral view of the environmental dynamics of pig waste by recognising the significance of reclamation practices as *escape valve* for excess waste from other in-farm waste management alternatives reported.

It is clear that agricultural reclamation of pig solid waste is concomitant to the availability of solid waste from in-farm waste management practices. It is often an implicit waste management alternative in pig farming even when farms implement other waste management alternatives. For that reason, provided the polluting capacity of solid waste, its agricultural or aquaculture reclamation constitutes a substantial part of the integral pig waste management. However, the prevailing environmental culture is geared towards the benefits of biogas and the synergy of energy cogeneration. Biogas production seems to provides a way out from a problem that is complex and whose regulation appears to be extremely difficult.

Conclusively, the practice of pig solid waste reclamation is critical to the environmental dynamics of production, yet it is largely overlooked in formal environmental frameworks over pig waste. Its absence challenges the environmental culture which seems to drive present environmental policies in animal production. For that reason, the overall picture of waste reclamation in the environmental dynamics of pig production in Thailand resembles the situation of the technological regime presented by Vanloqueren & Baret (2009). In a parallelism with the technological regime, it would require a shift in the current regime or environmental culture to allow a formal recognition and inclusion of waste reclamation and agroecological paradigms into the development of policies over animal waste management. It is also important to notice that the present environmental culture seems to differ from the actual environmental dynamics of waste management which in effect follow Holling & Meffe (1996) paradigm. This paradigm is relevant to this thesis because it defines a conceptual rather than prescriptive approach in management. This conceptual approach, as opposed to a prescriptive one in the form of standards, is termed "*retention of the natural state rather than [the] manipulation of system components or dynamics"* (Holling & Meffe, 1996).

This thesis suggests that present policies and dominant environmental culture overlook actual environmental dynamics in the scaling up of production, particularly, in terms of production structure. The focus of policies is on technological solutions at the individual farm level. As a result, informal practices on waste reclamation along the scaling up of production have become a non-planned adaptation that takes the place of a policy response. On one hand, we cannot dismiss the value of these practices in waste management, on the other hand, we cannot assume a direct and efficient scaling up of waste reclamation developing in parallel to the scaling up of production.

The persistence of this practice and its role in the environmental dynamics of pig production provide an opportunity for the development of informal practices into formal policies beyond actual approaches based on wastewater and animal in-farm management level. This opportunity for development carries theoretical implications. What could be understood out of the hypothetical situation where such practices were to be formally incorporated into environmental policies? First, such projection would uncover a case where informal and potentially viable practices contrast with the present environmental culture, a culture which seems to stress technological solutions and dominates policies; second, the institutionalization of such informal practices incorporated into policies would formally set the environmental externalities of animal production within an agroecological paradigm.

Ultimately, agricultural reclamation of animal solid waste is affected by institutional frameworks, including sectorial policies and competencies of relevant agencies. The informal use of animal waste in agriculture might be a common practice, but its institutionalization into environmental governance affects and is affected by multiple factors; including knowledge transfer mechanisms and legal compliance. Nonetheless, under present production scenarios, the functioning of solid waste remains an informal practice and a non-planned adaptation to the scaling up of production.

3.4 Institutionalization of Waste Reclamation

In contrast with waste reclamation as a non-planned adaptation, facing the environmental costs of pig production, Thailand has put forward formal policy instruments for animal waste management; for example, providing assistance to farmers in the environmental management of livestock by developing a *Compliance Assistance Centre* (Simachaya, 2008) or materials such as the *Decision Tree Model* or *Guideline for Clean Production for Pig Farms* (PCD, 2007). According to Dr Simachaya (personal communication, August, 2008) from the Thai Pollution Control Department, these efforts are mainly directed to improve compliance with pig effluents standards. However, Dr Simachaya claimed, the concept of diffuse pollution was starting to receive attention in the organization. Therefore, expert interviews revealed that environmental governance of livestock in Thailand is beginning to look beyond effluent-based standards because present standards and other regulations potentially applicable to pig waste management —e.g., Water Characteristics Discharged into Irrigation Systems (Royal Irrigation Department Order No. 883/2532, 1989)— are essentially limited to point pollution and address pig waste as wastewater.

In this line, defined as off-site management, furtherance of present reclamation practices for their integration with on-site management would contribute to agri-environmental policies in correspondence with agroecological paradigms. At the same time, a development of agri-environmental policies would signify an acknowledgment of the environmental significance of reclamation practices in agroecological systems beyond small scales of production to structures of production and production levels set by the scaling up of livestock.

Moreover, another view mentioned in this thesis is that different agro-ecosystems have specific bio-physical conditions and these may result in different pollution buffer capacities (see for instance Chambers et al., 2008). Therefore, nutrient concentrations could be defined by the level which does not alter the ecological conditions in a given agroecosystem (Chambers et al., 2008). Such definition brings the development of environmental thresholds to the ecosystem level. Although this is without a doubt a very attractive view, the level of knowledge, political and social compromise over the ecosystem in question would need extensive attention.

In general, guidance provided by governments on manure management is based on physical geography characteristics with factors such as land area, soil structure or rainfall, often, adding other factors relevant to the crop in place. These variables are integrated to build models such as NuFlux (Fachhochschule, 2006), a model applied to livestock production in Thailand and other countries (Menzi, 2002; Menzi et al., 2002). Currently, STRAW[12] offers an applicable model relevant to the concept offered in this thesis. It provides manure application rates for its use in agriculture to assist farmers with waste management. However, the use of nutrient budget models are subject to limitations derived from the nature of manure because, as seen earlier in the text, manure characteristics are variable and depend on multiple factors. One example of a nutrient model used as policy instrument in the environmental management of animal waste is MANNER (MANNER, 2000) in the United Kingdom. Farmers can use MANNER to keep manure use below a legal standard. In this line, STRAW could be used in a similar way. However, in any case, the additional transfer process of waste management from animal farmer to agricultural or aquaculture farmer would need further attention.

Another question in need of attention derives from the complexity in the environmental dynamics of pig production. This is, complexity in terms of how such dynamics affect manure characteristics and, particularly, in terms of waste reclamation practices by agricultural or aquaculture farmers. In this regard, farmers might see the setting of discrete standards for manure use as an oversimplification, in a similar manner to that described by Rigg (1985) in relation to farmers' views on fertilising recommendations. Factors such as farms proximity, transportation cost, land quality, price of chemical fertilisers, beliefs over the potential of manure, the choice of crop or expectation over outputs can all lead to different strategies in waste reclamation practices by agricultural farmers.

Although some countries have implemented approaches giving farmers autonomy in how to comply with regulations, i.e., in the Netherlands, "*freedom to stop nutrient leaks where they considered as most effective in their specific situation*" (Schröder et al., 2008); however, placing this concept within regulations is difficult because it conflicts with the EU legislation (*Ibid*) based on specific numeric standards for land application (Nitrates directive 91/676/EEC, 2000).

Moyer et al. (2008) argue about the failure of classical governance on animal waste management in Manitoba, Canada and propose empowering communities in pig waste management through community-based management and monitoring of animal farms.

[12] *Test version provided by Dr Gerber, personal communication, June, 2010*.

Citing Noble (2005), Moyer et al. (2008) define monitoring as *"activities that involves observing and describing changing conditions…, potential causes of those changes, and translating data into useful information"*. It seems like waste reclamation practices by agricultural farmers resemble this set of actions and, moreover, as opposed to livestock farmers, for whom the practice might just work as waste removal, agricultural farmers are likely to make the most of waste reclamation because they bear the cost and labour of manure use, reasons that have shown to prevent manure use (Rigg, 1985).

Vandergeest (2007) describes a similar case in the cooperative regulation and management of sediments from shrimp production in Thailand. His research on the role of government institutions and environmental management in shrimp farming in Thailand suggests that farmers believe they exert their own commitment in addressing environmental problems. Farmers interviewed about the environmental impacts of shrimp farming reported that in order to maintain good relations with neighbours they disposed sediments in a responsible manner (Vandergeest, 2007). Furthermore, despite the existence of a number of regulations in shrimp farming, farmers did not recall them (Ibid).

In the case of pig production in Thailand, this thesis postulates that in contrast to the case in Vandergeest (2007), the scaling up of production involves one more actor in addition to the waste producer: the agricultural farmer. This additional actor adds complexity to the case of pig farming with dynamics consisting on on-site and off-site waste management by different actors. This dynamics can be even more complex if aquaculture is included. The added complexity with the inclusion of a second and even third actor will need to be considered when addressing the institutionalization of reclamation practices.

Moreover, given the off-site nature and transfer from livestock to agriculture, waste reclamation affects and is affected by the competences of numerous governmental agencies (Kongsricharoern, 2008), some of which would not otherwise be involved in the environmental management of livestock. For instance, Thailand's Pollution Control Department provides advice on waste management; however, agricultural production and issues related to fertilisation depend on agricultural bodies, animal production depends on the Department of Livestock Development, rice production on the Rice Development Department and land use planning on the Land Development Department. Therefore, an added complexity to policies in waste reclamation in agriculture is the number of agencies involved. Drawing from Kongsricharoern (2008), the number could reach 20 bodies in addition to their ramifications to regional, provincial and local levels. Given the complexity and number of actors involved in agricultural waste reclamation, this thesis would recommend an actor network analysis (Hermans & Thissen, 2009) to analyse the large number of parties influenced and influencing a possible incorporation of waste reclamation practices into formal environmental frameworks.

In terms of waste reclamation in agriculture, manure use depends on practices and knowledge by agricultural farmers over manure and chemical fertilisers. In this regard, whereas pig production in Thailand is considered of high standards (Gerber & Menzi, 2006), institutional frameworks and agencies such as agricultural extension services have been described in Agbamu (2000) as lacking linkages between agricultural research and extension organisations, lacking joint evaluation of on-farm trials, farmers' participation, joint decision-making and staff exchanges. This limitation in knowledge transfer reported by Agbamu (2000) might explain the low levels of tailored recommendations in rice fertilisation in Thailand noted in Haefele et al*.* (2006). For this reason, informal practices in animal waste reclamation in Thailand might be particularly subjected to non-planned adaptations by farmers. This can lead to practices that do not necessarily produce positive environmental results.

Expert interviews reveal the complexity against the definition and implementation of national or regional environmental thresholds in waste reclamation. Owing to this complexity, this thesis suggests that the formalization of waste reclamation practices should observe existing systems and adapt to the present functioning of off-site waste management. The analysis of information collected from primary and secondary sources shows that the development and implementation of land-based standards would be impractical given the environmental culture in place and the complexity in the geographical and environmental dynamics of pig production, adding uncertainties in the formulation of manure thresholds and challenges in compliance and coordination of the numerous agencies involved in the field.

This research therefore proposes that in the case of Thailand the institutionalization of waste reclamation needs to focus on the intersection of on-site and off-site waste management. This intersection represents the transfer of waste between livestock farming and agricultural or aquaculture farming. Given the market-based solution already in place, the Fertiliser Act of 2518 BE (noted firstly in section 2.3.3) could be used as a framework to articulate the regulation of the practice. The regulation would require livestock farmers to record waste transfers and provide an estimation of the nutrient(s) content of manure to agricultural or aquaculture farmers collecting manure from the pig farm.

The transfer of information to agricultural and aquaculture farmers would allow them to exert certain control over the use of manure in their economic activities as well as on potential environmental impacts that such activities might cause. This transfer would also serve to strengthen the knowledge transfer mechanisms in agriculture in view of the low knowledge transfer reported by Agbamu (2000). In line with international programmes, the STRAW model can support the articulation of this information at field level. Moreover, this method would reduce the number of agencies involved and integrate their competences in order to allow a high degree of independence in their functions in the formalization of reclamation practices as off-site waste management. The main agencies directly involved would be the Pollution Control Department, the Department of Livestock Development and those in the role of Agricultural Extension. Consequently, this strategy suggested would not substantially challenge the present *status quo* of waste reclamation since it does not require a fundamental change in the present environmental culture and neither does it require a high level of coordination among agencies. The strategy would contribute to preventing agencies from having to face what could be interpreted as a change in their institutional culture. Echoing Holling & Meffe (1996), the strategy is based on a conceptual rather than prescriptive approach.

Pig farmers, and by extension all animal farmers, are not imposed restrictions in production. Therefore, farmers shall not understand this regulation as a normative standard, but rather shall understand it as beneficial for manure trade, one reason being the transfer of information to the agricultural or aquaculture farmer. This is important because, ultimately, the implementation of waste management programmes relies on farmers accepting such programmes. If implementation is based on present practices, prospects and sustainability of the policy increase. This would allow formalising off-site waste management by integrating actual waste reclamation practices into environmental management of livestock farming. To this effect, the implementation of this policy could be presented as *descriptive* and not as normative, commonly identified with command-and-control regulations.

A successful implementation would move agri-environmental frameworks a step closer to an environmental culture less antagonistic to the notion of agroecological innovations noted by Vanloqueren & Baret, 2009). In this context, other options and perspectives over agri-environmental management, such as multifunctional view of agriculture (Renting et at., 2009) and payments for environmental services (PES) (Wunder et al., 2008) might enter the environmental dynamics of animal waste in Thailand. For instance, PES could be applicable in cases where a market solution is not feasible because of geographical or agricultural distribution conditions. However, it is important to recognise that the environmental dynamics of pig production in Thailand make the case different from PES cases found in literature in relation to the recycling of animal manure and nitrogen levels. In those cases, waste producers and PES beneficiaries were the same farmers [actors] (see for instance Perrot-Maître, 2006); however, in the case of Thailand there is a transfer of waste and therefore of management between pig and agricultural farmers. Therefore, the concept of PES schemes applied to the case of waste reclamation in Thailand would not necessarily work out as those found in the literature. Such schemes would need to be adapted by targeting the animal farmers or agricultural [and aquaculture] farmers according to the conditions which give birth and set forth a given PES scheme, including environmental, agricultural and livestock geography factors.

3.5 From Environmental to Agricultural Geography

The recognition at policy level of pig solid waste reclamation practices would signify a formal acknowledgement of their environmental significance based on the notion that off-site waste management complements in-farm [on-site] prescriptive management to comply with effluent standards. Both on-site [in-farm] and off-site environmental processes need to be taken into account from the perspective of geography in order to draw a complete picture of the environmental dynamics of pig production. Accordingly, information obtained from the proposed *descriptive* policy would support a deeper understanding of the environmental dynamics of pig production in terms of nutrient balances and actual linkages among livestock, agriculture and aquaculture. The information could also support mapping systems and be articulated for specific objectives under a geographical perspective, both under areas defined by human geography (i.e., province) or physical geography (i.e., watershed). This geographical perspective would support the alignment of environmental policies with agroecological frameworks as well as it would support further examination of environmental determinants in the geography of livestock. All in all, the environmental dynamics resulting from the scaling up of pig production reveal the significance of environmental determinants in the geography of livestock. The integration of waste reclamation practices into policies would formally recognise the connection between environmental and agricultural geography. Moreover, this thesis claims that the formalization of waste reclamation would affect traditional views of agricultural geography.

In traditional agricultural geography, the significance of *environment* is based on the impact of the environment as a determinant of outputs from agriculture (Symons, 1972: 21), a view based on the biological nature of agriculture (McCarty & Lindberg, 1966). Nowadays, a [partial] independence of agriculture from local environmental conditions, particularly in industrial livestock, and the spatial detachment of livestock from agriculture have brought in a new notion of *environment* in contrast to that from traditional agricultural geography.

The environmental dynamics described in this thesis illustrate this notion of *environment* as an externality of production caused by the environmental impacts associated with livestock. This is, the scaling up phenomenon endows *environment* with a meaning promoting a different view of agricultural geography. Nonetheless, this notion of *environment* does not necessarily conflict with the original one in agricultural geography because livestock waste maintains its agricultural value. This agricultural value is indeed the reason why agricultural and aquaculture farmers collect manure from pig farms. In this sense, livestock [waste] maintains its meaning as determinant of outputs [environment as resource], at least in the view of agriculture or aquaculture farmers collecting manure from pig farms.

This duality of meanings is central to this thesis because it sustains the agroecological paradigm just as it pinpoints the close relation between environmental geography and agricultural geography in livestock production. A close relation recognised through off-site waste management in the environmental dynamics of pig farming.

The notion of e*nvironment* drawn from environmental geography construes a geography of agriculture [including livestock] beyond the notion of *environment* as determinant of outputs. Consequentially, out of this duality emerges an alternative reading on how intensive livestock production can redefine agricultural geography by incorporating environmental geography. Traditional agricultural geography defines livestock by *location* as opposed to *distribution,* the latter attributed to plantations [agriculture] due to their extensive use of land (Ilbery, 1986). However, in the environmental dynamics reported in this thesis with regard to pig production in Thailand, the new notion of *environment* drawn from the significance of off-site management shifts the view of intensive pig farms from *location* to *distribution*. In addition to the absolute location of animal farms, off-site waste management defines pig farms' relative distribution according to the farms' environmental dynamics.

In this scenario, environmental dynamics are contingent to the agricultural and environmental geography of a given area defined by either human or physical geography features. Therefore, the notion of geographical distribution of pig farms according to the agro-environmental dynamics of pig production is not necessarily related to space in a direct proportional scalar manner to the location of farms and consequently might not follow a thünian model. The distribution depends on variables in environmental and agricultural geography at several hierarchies and scales and, importantly, on agricultural and waste reclamation practices, including the environmental performance and allocation of agricultural land by agricultural farmers conducting waste reclamation. As seen in the literature (Gerber & Menzi, 2006; Rigg, 1985) and addressed in expert interviews, e.g., Dr Duangpatra (personal communication, August, 2008), transfer of waste from animal farmers to agricultural farmers is likely to be a function of the distance to suitable agricultural land and how agricultural farmers value benefits against labour and transportation costs of pig solid waste. From this viewpoint, the concept of distribution as addressed above can be interpreted as an *extended area of environmental influence*. The definition of this *extended area of environmental influence* depends on the function of waste reclamation for the pig farm and the performance at agricultural level. For this reason the functioning of waste reclamation as off-site waste management and the associated agricultural practices should further be understood.

Since the scaling up of production stresses the significance of this *extended area of environmental influence,* the scaling up reveals a transformation of livestock intensive operations in agricultural geography from location to distribution. This transformation is based on the integration of environmental geography into agricultural and livestock geography within the paradigm of agroecological sustainability, especially, in relation to waste reclamation practices at large scales of production.

Several factors can influence the availability or excess of manure and the environmental performance of agricultural practices in its function as off-site waste management. In addition to the most direct factor, the value of manure in agriculture or as fish feed, there are other direct factors. These include the geography of livestock (density of livestock and proportion of pig farms and size relatively to other livestock), specific in-farm environmental management and that in nearby farms, regional agricultural geography (e.g., dominant regional crop) and land development (i.e., proximity to residential or industrial estates). Other factors include social acceptance by neighbours or price and reliability of chemical fertilisers. All factors are important because they might greatly influence the policy proposed in this thesis. Moreover, these factors brings about several questions in relation to the agricultural value of manure as a fertiliser or soil conditioner compared to that of chemical fertilisers (Schröder, 2005).

The total value of manure is a complex question because it does not only depend on the quality of manure in terms of nutrient concentration but also on the overall cost of manure use and practices by farmers. It can vary greatly depending not only on pig farming but also on factors beyond pig farming; from natural processes in plant uptake and soil conditions (Sørensen & Jensen, 1995), to the type of pig farm, i.e., weaning or fattening farm (Sanchez & Gonzalez, 2005), in-farm practices such as waste storage (Petersen et al., 1997), or waste treatment (Bernal et al, 1992; 2009; Bertora et al., 2008). The value agricultural farmers give to manure is therefore affected by practices at pig-farm level and also by natural, environmental processes and agricultural practices beyond livestock farms, at locations where waste is used.

Factors affecting the value of manure at both livestock and agricultural farm level limit the theoretical approach of models where nutrients produced at animal farm level match their use in agriculture under calculated nutrient budgets. In this context, notwithstanding the value of animal waste in agriculture, the complexity of analysing environmental inefficiencies in waste reclamation in agriculture is evident when projected to large geographical scales, whether defined by human or physical geography. In this notional projection to large geographical scales is where this thesis defines the *extended area of environmental influence* of livestock production. This concept can be fitted to the desired geographical level or scale, be it human or physical geography, e.g. province, watershed.

Ultimately, the interpretation of environmental determinants in agricultural geography remains a question of values at management and policy level (*cf* Ludwig, 2001). This thesis offers an interpretation of how pig waste reclamation dynamics have been transformed by the scaling of production and how this transformation allows a reading through agroecological paradigms (*cf* Vanloqueren & Baret, 2009). This interpretation is approached at policy level through the acceptance of present practices and the recognition of the aforesaid notion of environment in agricultural geography, a notion framed in ecological cycles of nutrients and food production and therefore in the ecology of food systems as defined in Francis et al. (2003).

The evidence of Francis et al. (2003) ecology of food systems in agricultural geography offers a contrasting view to that proposed by Atkins (1988) of agricultural geography as the geography of food. Indeed, this thesis recognises agricultural geography as the geography of food as a common view nowadays. See for instance the Barsac Declaration or Herrero et al. (2009) quoted below.

> "*Demand for livestock products needs to be reduced in places where environmental impacts are currently or potentially severe".*
>
> *Herrero et al. (2009)*

The Barsac Declaration is a global initiative launched in 2009 to call for attention on the environmental menace from reactive nitrogen symbolized by the 2004 Nanjing

Declaration[13]. The Barsac Declaration was launched by a group of scholars, mostly specialists in nitrogen, to make public their belief that, in addition to government actions, a personal compromise is needed to prevent environmental impacts from animal production. For that reason, the declaration advocates lower meat consumption to influence markets, as less meat demand means less production which in turn equates to less animal waste.

The Declaration shows that the environmental externalities from animal production have reached such a level as to prompt experts to advocate for a change in consumption habits. This approach or understanding also seen in Herrero[14] et al. (2009) quote, follows the perspective of the geography of food because both seem to focus on the power of consumers to control the environmental impacts of animal production.

These claims on the power of consumers and the environment are not generally based on the natural sciences but they draw on the social sciences. However, regardless of the uncertainties that science presents for the management of the environmental effects of livestock production, social sciences also presents deep challenges in explaining or predicting sustainable consumption habits. Movements promoting more sustainable consumption habits might not be as popular or as influential in developing countries as they are in the richer world. Moreover, the globalization of food production may cause livestock production to move geographically. Therefore production might not necessarily follow local demand or local demand follow local production. Drawing on Winter (2003) Robinson (2009) writes regarding debates over sustainable agriculture that some of this demand for *local* or *quality* food reflects a "*defensive localism and not a strong turn to...ecological production*". In many cases, production might simply move geographically following the pollution haven hypothesis.

On the other hand, the Barsac declaration and Herrero et al. (2009) reflect agricultural geography as a thünian model of agricultural production where the location of production follows demand. Although such thünian model might often be the case, and social movements might, to some degree, prevent environmental impacts from livestock production, there is also an alternative view through the lenses of agroecology.

[13] *The Nanjing Declaration on Nitrogen Management was presented at the conclusion of the 3rd International Nitrogen Conference on October 16, 2004 and presented to the United Nations Environment Programme. www.initrogen.org/nanjing_declaration.0.html (accessed April 2010). http://www.nine-esf.org/barsac-declaration (accessed April 2010).*
[14] *Nonetheless, Herrero et al. (2009) does mention agroecology and de-intensification of livestock.*

This view is supported in this thesis by looking at the case study of Thailand. The case study allows a glimpse into the environmental significance of off-site waste management and the integral environmental dynamics of pig production; and, moreover, a glimpse into how the formal recognition of such dynamics could transform the definition of livestock in agricultural geography from location to distribution as *extended area of environmental influence*. The case study shows that the scaling up of production discloses the significance of environmental geography in pig production. Environmental geography transforms the traditional view of agricultural geography and informs policies for the agri-environmental management of animal and agricultural production.

4. CONCLUSIONS

Following previous studies, this thesis acknowledges a transformation of livestock production in Thailand. This transformation is described within the pig production sector and defined as a scaling up, first, in the average size of commercial farms in terms of absolute animal numbers [stock]; second, in the share of domestic production originated in a farm-type characterised by industrial and intensive commercial methods; and third, in the geographical concentration of production. As a result, scaling up processes have restructured production from a system based on small-scale farming to a system nowadays based on fewer but larger specialized farms.

This thesis found methodological limitations for the definition of farm sizes and therefore for the characterisation of the above-mentioned scaling up of production. Nevertheless, this thesis suggests that the scaling up in Thailand has led to a pig production structure based on a farm-type identified in this thesis as medium-scale farm. Accordingly, medium-scale farms provide the larger share of domestic production compared to that from small and large farms. Medium-scale farms and their predominance in total production are interpreted as symptomatic to the scaling up of pig production.

Consequential to the scaling up and spatial concentration is the production of large volumes of localized animal waste. Given the size and nature of medium-scale farms, the scaling up of production brings about a scenario where pig farming requires explicit environmental management, as pointed out by Gerber (2006), regardless of regional location. Moreover, given the role of medium-scale farms in domestic production, environmental management in this farm-type represents and defines the environmental dynamics of pig production resulting from the scaling up of production. For that reason the functioning of environmental practices concerning medium-scale farms is highly significant to environmental policy development over livestock.

In this regard, the environmental dynamics of pig farming in Thailand shows that in-house solid waste separation and its agricultural reclamation remain common practice in the waste management of medium-scale pig farming. Moreover, it seems that manure use as fish [freshwater] feed is also common. In-house waste separation generally means the removal of pig solid waste from floors before animals and floors are washed and waste flushed to become wastewater. Pig solid waste is then used in agriculture following traditional use of manure as fertiliser or soil conditioner. Some studies label pig solid waste reclamation in agriculture as *organic fertiliser* and present it as a waste management alternative adopted by pig farmers. However, this thesis states that, although pig farmers can adopt other alternatives for in-farm waste management, the disposal or reclamation of pig solid waste in agriculture provides a partial or total but the final solution to what other waste management alternatives cannot achieve. Therefore, ultimately, disposal or reclamation of pig solid waste in agriculture functions as a complementary and conclusive solution that significantly facilitates the environmental management of pig production. For this reason, this thesis suggests that agricultural [and aquaculture] reclamation of solid waste is crucial in present waste management even for pig farms formally adopting other recognised waste management alternatives such as biogas technology. Therefore, characteristics, conditions and practices in medium-scale pig farming affect agricultural reclamation as a waste management alternative.

In this line, this thesis holds that scaling up of production has not prevented waste management practices based on solid waste separation. In fact, the scaling up of production has enhanced the significance of such practices in the environmental dynamics of pig production because the availability of pig solid waste allows its causal or purposive agricultural [and aquaculture] reclamation. For this reason, this thesis recognises the environmental significance of pig solid waste reclamation and explores its integration into environmental policies on animal production. One important aspect is that, due to the scaling up of animal production, reclamation practices are not taking place under traditional low-scale production scenarios and the environmental dynamics these practices endow cannot be simply understood as a direct projection from traditional to larger scales.

One transformation in the environmental dynamics is the scale and transfer of waste from livestock to agricultural [and aquaculture] farmers. Agricultural [and aquaculture] farmers collect solid waste [manure] from pig farms with collateral benefits for livestock farmers from both the trade and removal of solid waste from the farm. This thesis indentifies this transfer of waste management from animal to agricultural [and aquaculture] farmers as a key link in the environmental dynamics of pig production in Thailand. This thesis views the practice as crucial for the environmental management of pig production in Thailand and yet largely overlooked in environmental policies over pig production. To date, no policy addresses this transfer of waste. This creates a legal vacuum in the continuation of waste management practices unfolding through agricultural [and aquaculture] reclamation of commercialised pig solid waste.

Moreover, manure use in agricultural is not necessarily free of detrimental environmental effects from potential inefficiencies in waste reclamation. Therefore, although this practice works as waste management for pig farmers, in effect, its environmental significance depends on the environmental performance of waste reclamation practices conducted by agricultural [and aquaculture] farmers. If the environmental performance is appropriate, this thesis suggests that waste reclamation can be defined as off-site waste management and complement in-farm [on-site] prescriptive management to comply with effluent discharge standards. Pig waste management could be seen as a two-phase system, a first phase based on the differentiation of wastewater and solid waste, and a second phase based on the differentiation between in-farm [on-site] and off-farm [off-site] waste management. Wastewater is managed in-farm whereas solid waste is stabilised in-farm and then managed off-site through agricultural [and aquaculture] waste reclamation. Effluent standards in Thailand cover the wastewater phase; however, there is no clear policy over the solid and off-site phase. Consequently, provided that off-site management of solid waste is an ongoing practice which environmental significance cannot be dismissed, this thesis states that, in the absence of its formal recognition, waste reclamation has developed as an informal practice representative of a non-planned adaptation to the scaling up of production.

This thesis interprets this adaptation as concurring with an agroecological paradigm for the environmental management of animal production and agriculture. It is unclear, however, if the environmental performance of waste reclamation in agriculture [and aquaculture] fulfils the function of off-site management within an agroecological paradigm. In fact, the assessment of such function is very complex, partly, due to the fact that scaling up of production has transformed waste use in agriculture at least in two ways. First, waste reclamation is often not directly conducted by pig farmers; second, it does not necessarily take place in the proximity of the animal farm where waste originates. Therefore, pig waste management, in effect, does not exclusively depend on the internal waste management at the livestock farm. The dynamics of waste reclamation in Thailand (i.e., transfer of waste and combination of factors affecting both livestock and agricultural farmers) limit the application of models where nutrients produced at animal farm level match their agriculture use under nutrient budgets.

For that reason, in addition to the geographical conditions that affect animal farms, the environmental function of waste reclamation is also limited by the geographical conditions that affect agriculture[15]. Geographical conditions in the environmental dynamics of pig production are defined by the environmental geography of both animal farms and agricultural land or plots. Environmental geography conditions (e.g., type of soils, weather seasonality or distribution of farms with respect to water bodies) determine directly or

[15] *including aquaculture*

indirectly the performance of waste reclamation as off-site waste management. Nevertheless, variables in the realm of agricultural and livestock geography might also depend on [the area's] environmental geography and therefore both are rather interlinked. Variables in the realm of agricultural and livestock geography might include: animal farms proximity, livestock densities, allocation of pig waste by agricultural farmers, dominant crops and seasonal cropping patterns, distribution and proportion of pig farms to other livestock farms, pig waste availability compared to that from other livestock, waste management alternatives adopted by other animal farms, price of chemical fertilisers, seasonal manure demand or excess in a given area.

This thesis underlines that the environmental dynamics of pig production go beyond a model of animal farms isolated from agricultural, livestock and environmental geography. The significance of present practices over pig solid waste reclamation, both at on-site [in-farm] and off-site waste management level, calls for its recognition at policy level to address the full environmental dynamics of pig production beyond the animal farm level. If this recognition takes place, this thesis argues, it would be at least to some extend as a result of the scaling up of animal production and the development of non-planned adaptations.

At policy level however, waste reclamation in agriculture is a difficult normative challenge for environmental policies, Regulations such as the EU Nitrate Directive are tinted with scientific uncertainties and can be seen as limitations for economic development. Nevertheless, present effluent standards for pig farms in Thailand are not exempted from serious shortcomings and therefore, although necessary, they seem insufficient to control pollution. In any case, one important challenge for the implementation of regulations with regard to waste reclamation in Thailand is the above-mentioned transfer process.

From another perspective, the recognition at policy level of present environmental dynamics would promote an alternative view of intensive farming in traditional agricultural geography, not as location, but as distribution, a distribution acknowledged in this thesis as *extended area of environmental influence*. In this fashion, the recognition of waste reclamation practices would set animal production closer to agriculture in terms of agroecological cycles. Moreover, such recognition would mean acknowledging the value of animal-crop integrated systems at non-traditional scales. Recognising the significance of waste reclamation would also bring about an opportunity for schemes of payment for agro-ecosystems services (PES) in areas where conditions prevent off-site waste management. However, the implementation of PES would need to reflect the transfer of waste from animal to agricultural [and aquaculture] farmers.

In order to assimilate present practices into livestock environmental policies, and since command-and-control (CAC) regulations (e.g., EU Nitrates Directive) are likely to be rejected by farmers, this thesis offers a strategy based on a descriptive approach to inform policies and accommodate present practices. This approach is presented as a way around to CAC. Furthermore, this strategy to integrate present practices into environmental policies would not require a major change in the dominant institutional environmental culture motivating policies and identified in this thesis as following a technological regime as opposed to an agroecological perspective.

To initiate this strategy it would be necessary to, first, describe how informal waste reclamation takes place and how it functions in relation to the integral farm environmental management, but also in relation to agricultural activities and potential environmental impacts; and, second, how interested groups would react or contribute to a policy that recognises and integrates such practices into formal environmental frameworks. For that reason, this thesis suggests the use of an actor network analysis to explore the institutional and social fabric of all agencies affected by or affecting reclamation practices. Furthermore, this thesis recommends a soil environmental quality survey to preliminary assess the environmental performance of reclamation practices at agricultural level. This survey ought to consider two main group variables: first, livestock and pig densities over agricultural land, and, second, agricultural land availability by animal farms. The first study has been noted in the text, the second has been preliminarily drafted and included in Appendix 3 of this thesis.

In conclusion, this thesis offers an outlook of the environmental dynamics of pig production in which agricultural [and aquaculture] reclamation of pig solid waste is acknowledged as off-site waste management taking over from on-site [in-farm] waste management. As a result of the scaling up of production, off-site waste management upholds the agricultural use and value of manure as an environmental practice from traditional small-scale farming to present scales and structures of production.

Moreover, present practices and environmental dynamics over pig waste management in Thailand illustrate the need to redefine agricultural geography through environmental geography. In this context, this thesis finds that present environmental dynamics allows an interpretation of *environment* beyond its connotation in classical agricultural geography. This interpretation offers a connotation where *environment* is significant to livestock because of the environmental disservices caused by animal waste due to the scaling up of production. This connotation of *environment* associated with off-site waste management in the environmental management of animal farms leads to a distribution of intensive farms by means of their environmental dynamics. However, notwithstanding the agricultural properties of animal waste, the complexity of analysing environmental disservices in waste reclamation in agriculture is evident when translated to large geographical scales that combine livestock and agriculture. For these reasons, this thesis suggest a model for the distribution of farms in terms of an *extended area of environmental influence* of farms. The definition of an *extended area of environmental influence* depends on the function of waste reclamation as off-site waste management at agricultural [and aquaculture] level and therefore at agricultural geography level. For this reason the functioning of waste reclamation as off-site waste management and associated agricultural practices should further be understood.

Overall, this thesis offers an interpretation of how the environmental dynamics of agricultural reclamation of pig waste have been transformed by the scaling up of production and how this transformation allows its reading through agroecological paradigms. The connotation of *environment* deducted from the environmental dynamics of pig production bears its significance for agricultural geography as determinant of ecological cycles of nutrients in livestock and agricultural production. Therefore, the scaling up of pig production in Thailand has resulted in environmental dynamics that reflects agricultural geography as Francis's et al. (2003) ecology of food systems. This reading contrasts with the technological regime dominating present environmental frameworks over animal waste management in Thailand.

To conclude, this thesis argues that this interpretation is applicable at policy level by means of a *descriptive* strategy to environmental policy development for the formal recognition and definition of present practices. The recognition of present environmental dynamics and the significance of *environment* beyond its classic connotation in agricultural geography would allow an understanding and definition of agricultural and livestock geography in which environmental geography is more realistically integrated.

Finally, understanding institutional, farming and environmental processes governing reclamation practices will be beneficial to future environmental policy developments in Thailand and other countries in the region likely to follow similar patterns in the scaling up of animal production.

APPENDIX 1: LIST OF EXPERT INTERVIEWS AND FIELD VISITS

Expert interviews, personal communications

1. Blanco, October 2007, group meeting, Dr Edgar Blanco. Biogas Engineer, Pilot Biogas Plant, Andigestion Ltd, Summerleaze Group, Waterbeach, Cambridge, United Kingdom.
2. Chaiyakul, September 2008, Dr Arux Chaiyakul. Department of Livestock Development, Livestock Waste Management in East Asia Project, Ministry of Agriculture and Cooperatives, Thailand.
3. Chantalakhana, July 2008, Dr Charan Chantalakhana. Animal Nutritionist, retired, former Director of Suwanvajokkasikit Animal Research and Development Institute, Kasetsart University, Thailand.
4. Chatsanguthai, September 2008, Dr Sommai Chatsanguthai. Environmental Engineer, Consultant to the Department of Livestock Development for the Livestock Waste Management in East Asia project, Ministry of Agriculture and Cooperatives, Thailand.
5. Duangpatra, September 2008, Dr Piya Duangpatra. Soil Scientist, Professor, Interdisciplinary Program on Sustainable Land Use and Natural Resources Management. Kasetsart University. Thailand.
6. Gerber, August 2009, via email, Dr Pierre Gerber. Livestock Policy Officer, Food and Agriculture Organization of the United Nations, Rome.
7. Kanto, August 2008, Dr Uthai Kanto. Animal Nutritionist, Suwanvajokkasikit Animal Research and Development Institute, Kasetsart University, Thailand.
8. Klaewtanong, August 2008, Dr Wimalin Klaewtanong. Water Quality Division, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand.
9. Kongsricharoern, September 2008, Dr Noppadol Kongsricharoern. Director, Thai Environmental and Energy Development Ltd., Coordinator of farmers group meetings and progress reports under the Livestock Waste Management in East Asia project, Thailand.
10. Lohawatanakull, October 2010, group meeting, Mr Chingchai Lohawatanakull. Vice Chairman, Director, Charoen Pokphand Group Co., Ltd., Thailand.
11. Naritoom, August 2008, Dr Chatcharee Naritoom. Social Scientist, Associate Professor and Deputy Director, National Agricultural Extension and Training Center, Kasetsart University, Thailand.
12. Polpraset, August 2008, Dr Chongrak Polpraset. School of Environment,

Resources and Development, Asian Institute of Technology, Thailand.

13. Schaffner, June 2010, via email, Dr. Schaffner. Researcher and author of Schaffner et al. (2010). Modeling the contribution of pig farming to pollution of the Thachin River. Clean Technologies and Environmental Policy, 12(4), 407-425.
14. Simachaya, August 2008, Dr Wijarn Simachaya. Air Pollution and Odour Control, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand.
15. Suthanaruk, August 2008, Dr Pornsri Suthanaruk. Environmental Quality Division, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand.
16. Thapinta, August 2008, Ms Sunee Thapinta. Water Quality Division, August 2008, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand.
17. Tungittiplakorn, August 2008, Dr Warapong Tungittiplakorn. Environmental Quality Division, Pollution Control Department, Ministry of Natural Resources and Environment, Thailand.

Field Visits

Field site 1. Freshwater fish farm, Nong Kai Province, Thailand, August 2008.

Field site 2. Pig farm (Farm Yasothon 1), Yasothon Province, 200 piglets and 100 sows, approximately. Under contract with agribusiness. No clear environmental management, conducts waste separation, wastewater conducted to pit, solid waste piled up, August 2008.

Field site 3. Pig farm (Farm Yasothon 2), Yasothon Province. 400 piglets and 200 sows approximately. Solid separation, solids are piled, artificial wetland system for wastewater with rubber plantation for partial use of liquid and solid waste. August 2008.

Field site 4. Pig farm (Farm Ratchaburi 1), Ratchaburi Province. 200 piglets and 10 sows approximately. No solid-liquid separation. No waste treatment. Small biogas reactor and artificial wetland implemented for research by the Asian Institute of Technology, August 2008.

Field site 5. Pig farm (Farm Ratchaburi 2), Ratchaburi Province. 5000 piglets approximately. Advance environmental management with biogas production. June 2010.

Field site 6. Composting site, Nakon Patom Province, site owned by a pig farmer, manure is treated and composted for later use in agriculture. August 2008.

Field site 7. Rice fields, Nakon Patom Province, fields owned by a pig farmer, manure is applied as fertilizer. August 2008.

Field site 8. Cassava fields, Nakon Patom Province, fields owned by a pig farmer, manure is applied as fertiliser and fields irrigated with pig manure extract. August 2008.

Field site 9. Pig production area, Nakon Patom Province, observed water bodies and canals from early hours to witness the dynamics of discharges from pig farms in an area with a high density of medium-scale farms. Locals reported that most farms in the area conducted solid-liquid separation, November 2009.

APPENDIX 2: LIST OF PHOTOS FROM FIELD VISITS

Photo 1. Water canal by several medium-scale pig farms.
Photo 2. Pig housing with non slatted floor in intensive farm.
Photo 3. Pig waste pit and retention pond.
Photo 4. Ponding system.
Photo 5. Facultative and aerobic pond.
Photo 6. Solid waste in pig pens.
Photo 7. Manual solid waste scraping.
Photo 8. Manure pile.
Photo 9. Basic manure management.
Photo 10. Advance manure management.

Photo 1. Water canal by in the proximity of several medium-scale pig farms. This picture shows a water canal functioning as a pig waste water collector in an area of high pig farming density in the proximity of the Thachin River, West of Bangkok, Central Thailand. Wastewater discharged from farms on daily basis allows the cultivation (circular green patches) of edible water plants, November, 2009.

Photo 2. Pig housing with non slatted floor in intensive farm. Non slatted floor allows scraping of solid waste. Many modern piggeries have slatted floors for slurry to seep trough to a collector from where it is pushed by wastewater from flushing the pens, Yasothon Province, August, 2008.

Photo 3. Pig waste pit and retention pond. After the removal of solids from the piggery floor, wastewater from flushing the pens is collected in a pit and a retention pond (left upper corner) with both showing signs of euthrohitation. This farm exemplifies how important it is for the farm's waste management the removal of solids by agricultural farmers, Yasothon Province, August, 2008.

Photo 4. Ponding system. Upon removal of solid waste from the piggery floor, wastewater might be treated in a ponding system. These systems can be sophisticated and in the case shown it includes a covered subsurface flow constructed wetland (notice the rubber leaning with water accumulation on the top) and a second and third polishing pond (right upper corner), Yasothon Province, August, 2008.

Photo 5. Facultative and aerobic pond. Following on photo 4, polishing ponds consisted on a facultative and aerobic pond with wastewater in excess discharged to a rubber plantation, Yasothon Province, August, 2008.

Photo 6: Solid waste in pig pens. Solid waste to be removed from the passageway, Yasothon Province, August, 2008.

Photo 7. Manual solid waste scraping, Yasothon Province, August, 2008.

Photo 8. Manure pile. After removal from pig houses, solid waste can accumulate outdoors on the bare ground, Yasothon Province, August, 2008.

Photo 9. Basic manure management. Manure is set to dry and occasionally turned over (notice clearer colour). Although marketable, it can take time before manure is taken away from the farms, Yasothon Province, August, 2008.

Photo 10. Advance manure management. Draining and drying of slurry, as well as of biogas digestate and pig solid waste, Ratchaburi Province, June, 2010.

APPENDIX 3: PROPOSAL FOR A SOIL ENVIRONMENTAL QUALITY SURVEY

A3.1 Introduction

Given the importance of agricultural practices in the analysis of waste reclamation as off-site waste management, this thesis proposes a Soil Environmental Quality Survey (SEQ-Survey) as a step forward for understanding the projection of traditional reclamation practices to current production scales. SEQ-Survey would explore the environmental performance of the practice at agricultural field level.

The SEQ-Survey would take place by selecting animal farms and their respective reclamation sites according to production and geographical variables such as livestock density, pig share in production and land availability. The survey would be based on estimates of solid waste intended for use in agricultural fields. Calculations in terms of nutrients budgets and land requirement would be conducted using the model STRAW[16].

The purposive site sampling would concentrate in animal production at the medium-scale size of farm under intensive husbandry practices indicative of the scaling up of production. The SEQ-Survey would measure soil environmental quality parameters in fields where waste reclamation takes place. Sites would be selected from pig medium-scale farms and their respective reclamation sites. Assessing the environmental performance of waste reclamation requires characterizing the physical environment (Murphy et al., 2004); therefore, in addition to environmental indicators obtained by direct measurement, other physical environment parameters (e.g., precipitation) would be obtained from literature. Soils would be characterized by the collection of parameters routinely used in soil quality evaluations. The central parameter tested at post-harvest would be Soil Residual Nitrogen (Nres) interpreted as indicator of environmental risk from nitrogen leaching (Drury et al., 2007; Rankinen et al., 2007; Sun et al., 2008; Zebarth et al., 1996). Nitrogen measures would be taken from soils before first waste application (usually at plowing) and after harvest. A second indicator would be water extractable phosphorous (soluble P) and total phosphorous, because according to Pote et al. (2003), a high original level of phosphorus in soils can affect the mobility of additional phosphorus applied to the soil. Selected environmental parameters would be measured from samples collected at two plots (see figure A3-1) per reclamation site; each plot corresponding to a different rice field.

[16] *Support for the Treatment and Recycling of Animal Waste (Test version provided by Dr Gerber et al 2010 in personal communication, June, 2010).*

The survey would require:

- Reported waste quantities used per site sourced in identified pig farms.
- Destination, target crop, location and manure use timing.
- Nutrients estimates in solid manure.
- Estimations of other possible local inputs of nitrogen, such as from irrigation or chemical fertilizers.
- Soil conditions, before plowing (before waste application).

Animal waste use in agriculture has been linked to the accumulation of heavy metals in soils (Zarcinas et al., 2004) and their availability through plant uptake (Simmons et al., 2008). Prachoom (2006) reported high levels of cadmium and arsenic in pig manure, and Yan-xia & Chen (2005) reported arsenic accumulation in fields with a long history of manure use. Zarcinas et al. (2004) attributed cadmium and zinc presence in relation to organic matter in soils to contamination from soil amendments (e.g., manures, composts).

Consistent with these findings, nutrient balance models, such as NuFlux (Menzi et al., 2002), include heavy metals, particularly cadmium and zinc. This proposal therefore suggest the inclusion of arsenic, cadmium, zinc and copper as environmental indicators. Since differences in metal concentrations within one year or one season might not be detectable, metals would be measured only at harvest and at one soil depth (approximately 30 cm as limit of root and ploughing zone and results compared against background levels (Hamon et al., 2004). Data collection would follow USDA (1999) standard procedures for soil sampling. Results would be compared across plots and sites by farm categories and locations to explore the environmental performance of reclamation practices. Additionally, a visual environmental survey for indications of nutrients surpluses (i.e., eutrophication) would be conducted in the proximity of reclamation sites.

A3.2 Farms and Sites Selection

Pig farms and sites selection would be conducted according to two variables: livestock density, and percentage of pig production to total livestock production by regional location and land availability.

Gerber et al. (2006) reports on pig manure being less valued in many regions of Thailand compared to other livestock waste. Accordingly, demand for pig manure compared to that from other livestock might vary locally. Therefore the survey would cover three different typologies of locations, all locations with a relative high proportion of pig stock over total livestock, but with variable total livestock density over agricultural land. institutional arrangements, such as data recording by official bodies (e.g., monitoring, compliance, agricultural land, livestock statistics or farm registrars) are organised at the provincial level and therefore such arrangements drive the selection of farms by provinces. This selection would allow the differentiation of pig manure use under three different scenarios as follows:

A) Location with high percentage of pig production and high livestock density.
B) Location with high percentage of pig production and medium livestock density.
C) Location with high percentage of pig production and low livestock density.

Another important determinant in the environmental dynamics and performance of reclamation practices is agricultural land. Agricultural land availability provides the means but also acts as a limiting factor to animal waste reclamation in agriculture. Waste reclamation hence is dependent on agricultural land availability and it is therefore significant to the environmental pressure livestock production exerts on the animal farmer. A second variable in the selection of farms would be therefore agricultural land availability by the pig farmer. The selection of animal farms by agricultural land availability would be based on a desk study from information provided by Thai institutions (i.e., Department of Livestock Development, Land Development Department and agricultural provincial offices). This information would be later validated by site visits upon agreement with farmers.

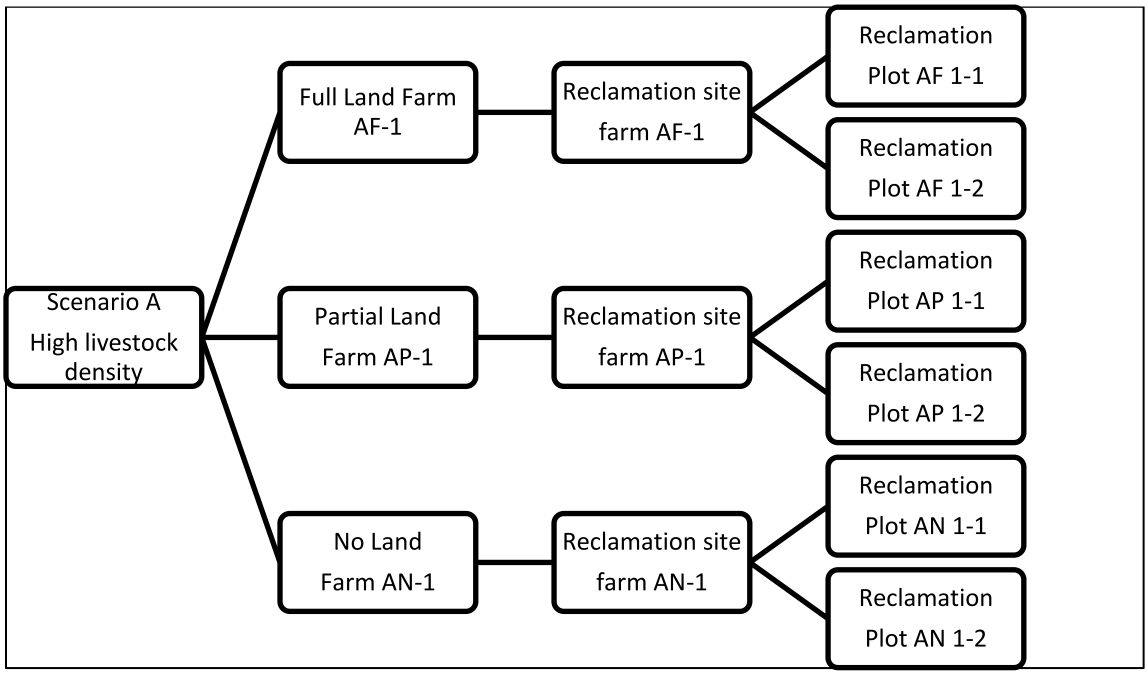
The land availability variable would include three categories based on the capacity of farms to utilize the solid manure they produce under the assumption of total solid manure use in agriculture. The land required for this full use would be calculated using the STRAW model above-mentioned. Categories would be as follows:

1. Full. Sufficient land: according to STRAW model under the condition that the pig farm has sufficient land for the reclamation of >90% of all solid pig waste produced.

2. Partial or limited land: according to STRAW model under the condition that the pig farm has sufficient land for the reclamation of 10% to 90% of all solid pig waste produced in the farm.

3. No land: according to STRAW under the condition that the pig farm has not or only sufficient land for the reclamation of up to 10% of all solid pig waste produced in the farm.

Figure A3-1: Example of farms and sites distribution for field survey according to land availability for scenario A: Location with high percentage of pig production and high livestock density.



A3.3 Data Quality

A purposive sample on nine reclamation sites would cover the variables mentioned with certain quantitative limitations. The survey proposed offers a compromise between sample size and data quality. The definition of farm categories [purposive scenarios] proposed is considered to offset the gains that a larger random sample would provide and which could nevertheless prove to be highly unrealizable. Another alternative would be to use a questionnaire and include a large number of farms and sites but not conducting the SEQ-Survey. One more possibility would be to collect data from fewer farms but with a more in-depth SEQ-Survey, for instance, by using lysimeters. These options could be addressed by limiting the survey to specific geographical administrative areas (e.g., province) or by the physical environment (e.g., catchment). Another option would be a controlled stratified large sample by farm size subdivisions and plantation type at reclamation site. This proposal, however, addresses the survey by selecting locations by pig production and livestock density over agricultural land and by land availability by pig farmer. This offers an attempt to adapt the research to the geographical mobility and fluctuations of production. Therefore, the proposed methodology by land availability, production and densities is deemed appropriate and the results could be analysed not exclusively by absolute location, but by variables defining the location.

The rationale behind using land availability by the livestock farmer is that specialization points to an increase in the number of farms likely to present limited land. The variable land availability (agricultural) is therefore essential; however, this would indicate the need for the livestock farmer to “outsource” waste reclamation and therefore the need to focus on the use of solid manure by the agricultural farmer and not necessarily by the livestock farmer. However, the research does not exclude this option as livestock farmers might also manage agricultural farm land and conduct waste reclamation as an agricultural practice.

Soil data collection can present important limitations. From sampling to analyzing, literature is full on debates on nitrogen data interpretation. In sampling, for instance, Giebe et al. (2006) showed that soil mineral-N content can greatly vary in short distances. In Giebe et al. (2006) up to 49% of variability was explained at spatial distances of 5 meters and with differences up to 26 kg N Ha^{-1} for soil depths 0-60 cm. This is not, however, expected to be a limitation in the present research since the research only intends a comparison pre and post-harvest and between farms and sites defining locations and waste reclamation scenarios and does not attempt the explanation of environmental processes. Finally, if possible, rather than depending on estimations of nutrients, manure in each site should be analysed for nutrients concentration and, as mentioned above, the survey would explore other sources of nitrogen.

A3.4 Ethical Issues

The main ethical issue for the research is how the research could affect animal farmers not complying with current regulations. This might force farms not to participate, disguise facts or distort data for fear of being reported or looked at as not caring for the environment. Willingness to participate might already filter farms to those applying certain level of treatment. This is actually a positive effect as the research is only interested in considering farms seemingly complying with effluents regulations by having certain level of waste management. The reason is that the focus of the survey is on the functioning and environmental significance of informal waste reclamation as part of the integral waste management and not in isolation. Therefore, although in-farm waste treatment is not a prime objective, poor waste management is likely to mean no waste reclamation. Therefore all farms surveyed must, at least, practise some form of waste management and separation as to allow waste reclamation by producing solid manure. Farms not undertaking any sort of waste treatment or reclamation have no application to the research.

On the other hand, there is the issue of cases on which the researcher might be asked for opinion or advice. For example, this could happen during the field survey because the information obtained could lead to fertilisation recommendation. However, providing opinion should be avoided as it breaks the researcher's role as an observer and could distort the research procedure and results by farmers altering their common practices. To prevent this from happening, farms would be provided with a written summary of the research inviting them to participate and collaborate and informing that all data would be anonymized. Upon research completion, farms would be provided with a report with information obtained from the field survey.

In terms of interviewees (government officers, experts or academia), the nature of the research should not initially carry any negative implications for the informants. However, information from interviews will not be anonymised because the research needs to cite, at least, the organization and affiliation interviewees belong to.

A3.5 Examples of Regional Location Selection

An example of the purposive farm selection process is presented here merely for explaining how sites selection would be conducted. Using data from GLIPHA (2009) on Thai livestock statistics, this example (Fig. A3-2) shows the ten provinces with highest pig share in total livestock (in LUs) and their respective total livestock density in agricultural land (LUs/Km^2) for each province. For this example, the chosen locations would be: for location in scenario A, Ratchaburi (2nd column Fig. 4 in main text) with 185.8 LUs/Km^2 (high livestock density); then for location in scenario B, Chiang Mai (8th column Fig. 4) with 65.9 LUs/Km^2 (medium livestock density), and finally, for location in scenario C, Chanthaburi (9th column Fig. 4) with 12.9 LUs/Km^2 (low livestock density).

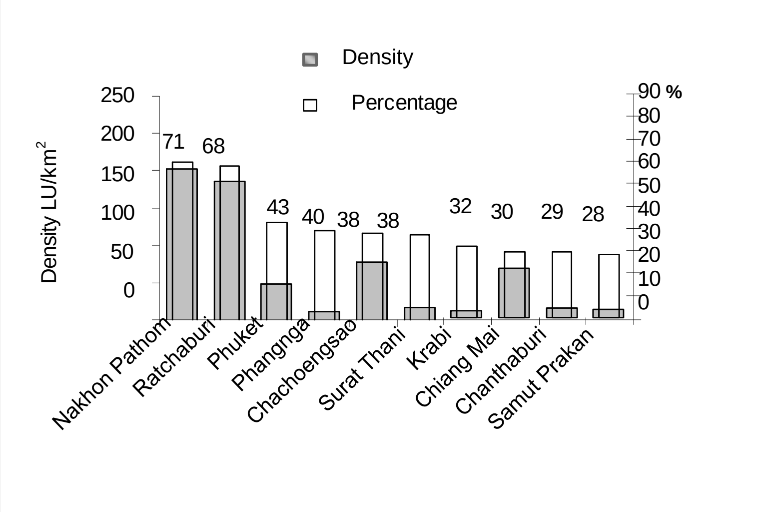
Considering that the national average of total livestock density in agricultural land for this data set is 43 LUs/Km^2 (maximum 227 LUs/km^2 and minimum 10 LUs/Km^2), the chosen provinces would rank in 3th, 10th and 71th in livestock density in agricultural land, all within the top 10 provinces in pig production percentage to total livestock production. This selection can be further divided or grouped by geographical location.

Table A3-1: Example of site selection and distribution of farms sampling for the proposed survey.

	Full	Partial	No land	Total per location
Scenario A Ratchaburi	1	1	1	3
Scenario B Chiang Mai	1	1	1	3
Scenario C Chanthaburi	1	1	1	3
Total for each land	3	3	3	9

Consequentially this selection allows the differentiation of these three provinces by: proximity to large urban area (Ratchaburi Province to Bangkok), proximity to small urban area (Chiang Mai Province to Chiang Mai) and no major urban area (Chanthaburi). Additionally, this selection allows the differentiation, in the same order, by regional location (i.e., Central, Northern and Eastern regions).

Figure A3-2: Top ten provinces in Thailand by percentage of pig production to total livestock production and their livestock density over agricultural land measured in LUs per square kilometre. Compiled by author using data from GLIPHA (2009).



A3.6 Paddy Rice

As mentioned in the main text, the environmental significance of land application of manure might depend on the crop in place. Therefore, for data consistency, the survey would only cover paddy rice crops (*Oryza sativa).* This crop has been chosen for its abundance in Thailand and Southeast Asia and because of its short agricultural cycle (approximately 3 months). Rice agricultural systems can, however, be rather complex, with practices ranging from monoculture (wet season) on a yearly basis, to double cropping (wet season and dry season), or rotational multiple cropping systems with diverse patterns (e.g., rice-onion-rice). To allow a comparative study, the research would be limited to one rice growing season at the same period of time across all sites. Unless there are very clear differences between different types of reported cultivars, there would be no distinction made between cropping systems, patterns or types of rice such as photoperiod sensitive and non-photoperiod sensitive varieties.

Figure A3-3: Example of environmental survey timeline (rice field).

Timing	Activity
Late July	Environmental Survey Manuring + Land Tillage + Planting (semi dry conditions) + Flooding
September:	Growing (flooded) considerable canopy cover
October:	Lowering water levels, ripening, semi dry or dry conditions, harvest
Late October	Environmental Survey (before remaining straw decays)

A3.7 Soil Sampling

Soil sampling would be conducted by removing the first 15 top centimeters of top soil by a standardised-size metal ring (see USDA, 1999) and a sample of soil drawn from the bottom of the ring. The same procedure would be repeated at 30-cm depth at a different spot from the former drill. Laboratory methods will follow common procedures in agricultural chemical analysis as described in Faithfull (2002). The 15 cm level is generally accepted as the rooting depth for rice crops. Several sources (Yoshida, 1981: 110-111; Smith & Dilday, 2002:369; Kusnarta et al., 2004) provide evidences supporting this depth. Smith & Dilday (2002:369) reported 90% of total roots in the top 20 cm and Sharma et al. (1987) reported approximately 75% of roots in the top 10 cm of soil. This depth is further supported by recent research studies, such as Schomberg et al. (2009), use similar depths. The lower depth of 30 cm is considered to be just below the root zone and is common depth reached by mechanical ploughing, e.g., mouldboard. Measurements at these two depths will allow the comparison of indicators levels in the arable soil layer and bellow the root zone at pre-application and post-harvest.

Parameters for the soil characterization would include: soil texture, structure, bulk density, Electric Conductivity, pH (lime potential and aluminum hydroxide potential), total carbon, soil respiration —used to model denitrification in soil— (Del Grosso et al., 2000), base saturation (calcium, magnesium, potassium and sodium), cation exchange capacity (CEC) and anion exchange capacity (AEC) —found to be important in the characterization of tropical soils (Lohse & Matson, 2005). Samples would be collected at two plots in the same reclamation site. Each sample would consist of three bulked and mixed sub-samples per plot at approximately 10 meters apart from each other. For measuring Electrical Conductivity, pH and soil nitrate, there will be eight cores sub-samples according to sampling recommendation by USDA (1999); if the water table is reached, sampling by hand auger might be required. Although nitrogen deposition is not included in the proposal, models such as Cannavo's et al. (2008) or Chen's et al. (2008) can be used. Likewise, fertiliser demand for rice and nutrient uptake can be obtained from literature, e.g., Haefele et al. (2006). On other note, Ros et al. (2009) point to the importance of dissolved organic nitrogen (DON) in the environmental impact of nitrogen. For this study, nitrogen in manure would be assumed to be highly mineralized because manure is usually dried for a considerable amount of time in the animal farm before it is taken to agricultural fields; nonetheless, since no specific differentiation would be provided, DON would be considered as included in total nitrogen.

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