Resource Assessment for Livestock and Agro-Industrial Wastes – Ecuador

Prepared for:

Global Methane Initiative

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EXECUTIVE SUMMARY

The Global Methane Initiative is an initiative to reduce global methane emissions with the purpose of enhancing economic growth, promoting energy security, improving the environment, and reducing greenhouse gases (GHGs). The initiative focuses on cost-effective, near-term methane recovery and use as a clean energy source. The initiative functions internationally through collaboration among developed countries, developing countries, and countries with economies in transition—together with strong participation from the private sector.

The initiative works in four main sectors: agriculture, landfills, oil and gas exploration and production, and coal mining. The Agriculture Subcommittee was created in November 2005 to focus on anaerobic digestion of livestock wastes; it has since expanded to include anaerobic digestion of wastes from agro-industrial processes. Representatives from Argentina, the United Kingdom, and India currently serve as co-chairs of the subcommittee.

As part of the Global Methane Initiative, the U.S. Environmental Protection Agency (U.S. EPA) is conducting a livestock and agro-industry resource assessment (RA) in Ecuador to identify and evaluate the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy.

The following table summarizes the findings of the RA in terms of potential methane emission reductions and fossil fuel replacement carbon offsets in Ecuador. The sector with the highest potential for methane reduction and carbon offsets is the ethanol sector, followed by the sugar, palm oil, and shrimp processing sectors. It is important to note that the swine and dairy sectors might also have some potential for methane reduction although they were not included in the calculations due to the limited availability of waste management system data.

Sector	Methane Emission Reductions ($MTCH_4$/yr)	Carbon Emission Reductions ($MTCO_2e$/yr)	Fuel Replacement Offsets ($MTCO_2e$/yr)	Total Carbon Emission Reductions ($MTCO_2e$/yr)
Ethanol	9,100	191,100	35,993	227,093
Sugar	3,707	77,844	0	77,844
Palm oil	2,465	51,767	9,750	61,517
Shrimp processing	802	16,845	3,173	20,017
TOTAL	16,074	337,556	48,916	386,471

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List of Abbreviations

AEBE	Asociación de Exportadores de Banano del Ecuador (Association of Banana Exporters of Ecuador)
AMBR	Anaerobic Migrating Blanket Reactor
ANCUPA	Asociación Nacional de Cultivadores de Palma Aceitera (National Association of Oil Palm Cultivators)
APROBANEC	Asociación Productores de Banano del Ecuador (Association of Banana Producers of Ecuador)
ASBR	Anaerobic Sequencing Batch Reactor
ASPE	Asociación de Porcicultores del Ecuador (Swine Association of Ecuador)
BCE	Banco Central del Ecuador (Central Bank of Ecuador)
BOD	Biochemical Oxygen Demand
CH_4	Methane (chemical formula)
CINCAE	Centro de Investigación de la Caña de Azúcar del Ecuador (Sugarcane Research Center of Ecuador)
CNA	Cámara Nacional de Acuacultura (National Aquaculture Association)
COD	Chemical Oxygen Demand
CORPEI	Corporación de Promoción de Exportaciones e Inversiones (Corporation for the Promotion of Exports and Investments)
DAF	Dissolved Air Floatation
DGP	Dirección General de Pesca (General Directorate of Fisheries)
ESPAC	Encuesta de Superficie y Producción Agropecuaria Continua. (Continuous Survey of Agricultural Area and Production) The data collection that takes place from October to December of the survey year in rural area through direct interviews with agricultural and agro-industrial producers
FAO	United Nations Food and Agriculture Organization
FEDAPAL	Fundación de Fomento de Exportaciones de Aceite de Palma y sus derivados de Origen Nacional (Foundation for the Promotion of Exportations of Palm Oil and Derived Products)
FFB	Fresh Fruit Bunch
GDP	Gross Domestic Product
GHG	Greenhouse Gas
Ha	Hectare
HRT	Hydraulic Retention Time
INEC	Instituto Nacional de Estadísticas y Censos (National Institute of Statistics and Census)

IPCC	Intergovernmental Panel on Climate Change
III CNA	Tercer Censo Nacional Agropecuario, año censal 1/10/99 a 30/09/00 (Third national agricultural and agro-industrial census)
INAMHI	Instituto Nacional de Meteorología e Hidrología (National Institute of Meteorology and Hydrology)
kg	Kilogram
L	Liter
LPG	Liquefied Petroleum Gas
MA	Ministerio del Ambiente (Ministry of Environment)
MAGAyP	Ministerio de Agricultura, Ganadería, Acuacultura, y Pesca de Ecuador (Ministry of Agriculture, Livestock, Aquaculture and Fisheries)
MCF	Methane Conversion Factor
MEyER	Ministerio de Electricidad y Energía Renovable (Ministry of Electricity and Renewable Energy)
$MMTCO_2e$	Million Metric Tons of Carbon Dioxide Equivalent
MT	Metric Tons
$MTCO_2e$	Metric Tons of Carbon Dioxide Equivalent
POPAE	Plan de Ordenamiento de la Pesca y la Acuicultura del Ecuador (Planning Program of Fishery and Aquaculture of Ecuador
ppm	Parts Per Million
RA	Resource Assessment
SESA	Servicio Ecuatoriano de Sanidad Agropecuaria (Ecuatorian Service for Agricultural Health)
SICA	Servicio de Información Agropecuaria del Ministerio de Agricultura y Ganadería del Ecuador (Agricultural Information Service of the Ministry of Livestock and Agriculture)
SRT	Solids Retention Time
TFF/H	Ton of Fresh Fruit per Hour
TOW	Total Organically Degradable Material in Wastewater (Annual mass of COD)
TS	Total Solids
TSS	Total Suspended Solids
UASB	Upflow Anaerobic Sludge Blanket
UPA	Unidad de Producción Agropecuaria (Agricultural Production Unit)
U.S. EPA	United States Environmental Protection Agency
VS	Volatile Solids

1. INTRODUCTION

The Global Methane Initiative is a collaborative effort between national governments and others to capture methane emissions and use them as a clean energy source. The Initiative, begun in 2004 as the Methane to Markets Partnership, was relaunched in 2010. Partners make formal declarations to minimize methane emissions from key sources, stressing the importance of implementing methane capture and use projects in developing countries and countries with economies in transition. The initiative is focused on a few key sources of methane, including agriculture, coal mining, landfills, and oil and gas systems.

The role of the initiative is to bring diverse organizations together with national governments to catalyze the development of methane projects. Organizations include the private sector, the research community, development banks, and other governmental and non-governmental organizations. Facilitating the development of methane projects will decrease greenhouse gas (GHG) emissions, increase energy security, enhance economic growth, improve local air quality, and improve industrial safety.

The Global Methane Initiative is conducting resource assessments (RAs) in several countries to identify the types of livestock and agro-industrial subsectors (e.g., dairy farming, palm oil production, sugarcane processing) with the greatest opportunities for cost-effective implementation of methane recovery systems. The RA objectives are to:

- Identify and characterize methane reduction potential in Ecuador
- Develop country market opportunities
- Provide the location of resources and a ranking of them

The main objective of this RA is to identify the potential for incorporating anaerobic digestion into livestock manure and agro-industrial (agricultural commodity processing) waste management systems to reduce methane emissions and provide a renewable source of energy in Ecuador. This report summarizes the findings of the RA, discusses the most attractive sectors and locations, and prioritizes the sectors in terms of potential methane emission reductions.

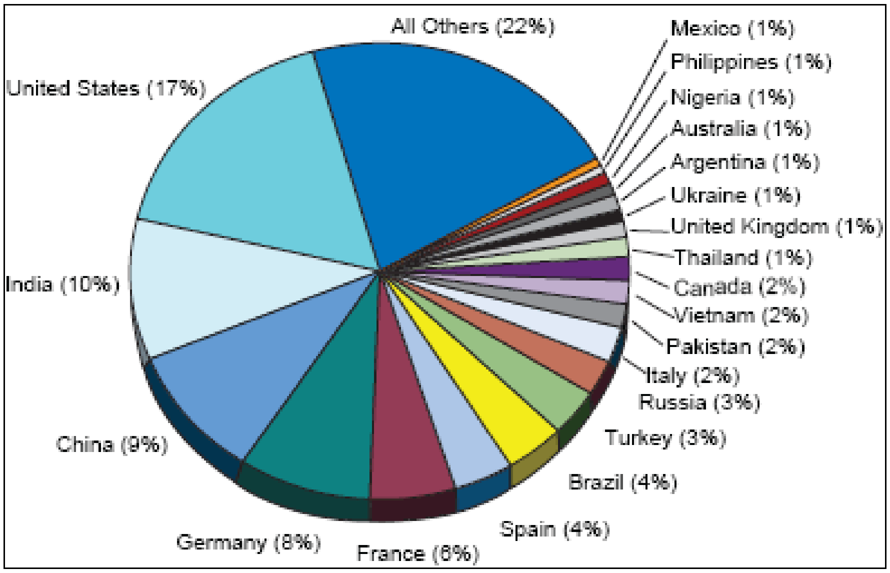
While there are other studies showing methane emissions from the sectors covered in this document, these studies usually take total population or production levels as the baseline for calculating the emissions. This RA, however, uses a different approach, recognizing that not all waste management operations (e.g., pastures) generate methane. For this analysis, methane emission reduction estimates are based on the actual population (or number of industries) that generate methane via their waste management system (e.g., lagoons) using the most accurate and validated data available for each subsector. For example, methane emissions from swine and dairy subsectors only take into account a reasonable fraction of the total number of animals and number of operations in the country. This fraction represents the number of animals that are assumed to be utilizing waste management practices that generate methane. Estimating emission reductions using these assumptions provides a better basis for policy development and capital investments and provides conservative estimates of emission reductions.

Finally, it is important to note that this RA limits its scope to emission reduction technical potential. It does not address the economic potential, which still needs to be determined based on subsector-specific feasibility studies.

1.1 METHANE EMISSIONS FROM LIVESTOCK WASTES

In 2005, livestock manure management globally contributed more than 230 million metric tons of carbon dioxide equivalent (MMTCO_2e) of methane emissions, or roughly 4 percent of total anthropogenic (human-induced) methane emissions. Three groups of animals account for more than 80 percent of total emissions: swine (40 percent); non-dairy cattle (20 percent); and dairy cattle (20 percent). In certain countries, poultry was also a significant source of methane emissions. Figure 1.1 represents countries with significant methane emissions from livestock manure management.

Figure 1.1 – Estimated Global Methane Emissions from Livestock Manure Management (2005), Total = 234.57 MMTCO_2e

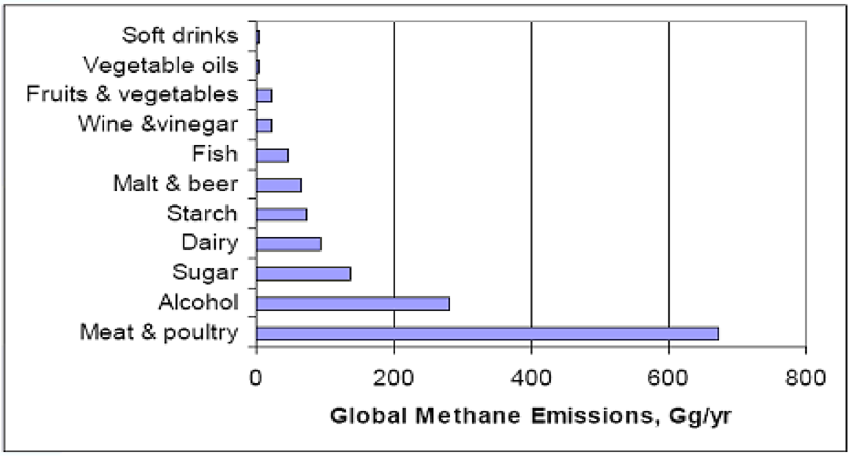


Source: Global Methane Initiative, Background Information

1.2 METHANE EMISSIONS FROM AGRO-INDUSTRIAL WASTES

Waste from agro-industrial activities is an important source of methane emissions. The organic fraction of agro-industrial wastes typically is more readily biodegradable than the organic fraction of manure. Thus, greater reductions in biochemical oxygen demand (BOD), chemical oxygen demand (COD), and volatile solids (VS) during anaerobic digestion can be realized. In addition, the higher readily biodegradable fraction of agro-industrial wastes translates directly into higher methane production potential than from manure. Figure 1.2 shows global estimates of methane (CH_4) emissions from agro-industrial wastes.

Figure 1.2 – Global Methane Emissions From Agro-Industrial Wastes



Source: Doorn et al., 1997

As shown in Table 1.1, the majority of agro-industrial wastes in developing countries are not treated before discharge, and only a minority is treated anaerobically. As a result, agro-industrial wastes represent a significant opportunity for methane emission reduction through the addition of appropriate anaerobic digestion systems.

Table 1.1 – Disposal Practices From Agro-Industrial Wastes

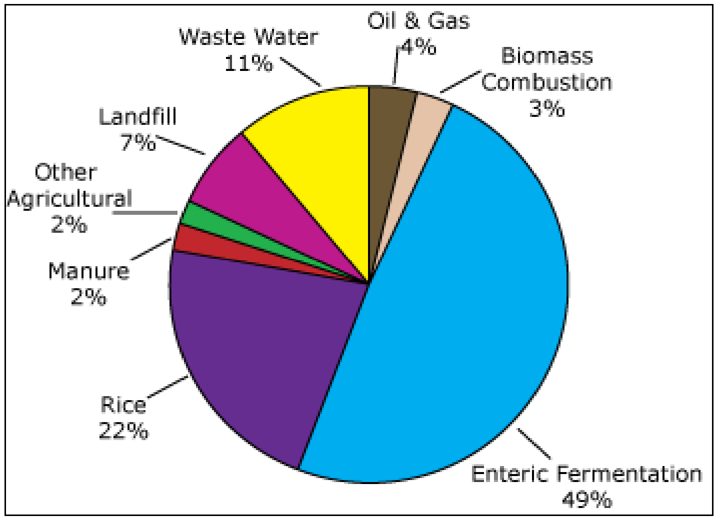
Sector	Region	% Wastewater	
		Untreated discharge	Onsite anaerobic treatment
Meat, poultry, dairy, and fish processing	Africa	60	34
	Asia (except Japan)	70	22
	Eastern Europe	50	23
	Latin America	50	32
Fruit and vegetable processing	Africa	70	6
	Asia (except Japan)	70	5
	Eastern Europe	50	1
	Latin America	60	5
Alcohol, beer, wine, vegetable oil, sugar, and starch	Africa	60	17
	Asia (except Japan)	60	11
	Eastern Europe	20	8
	Latin America	20	13

Source: Doorn et al., 1997

1.3 METHANE EMISSIONS IN ECUADOR

As part of its participation in the Global Methane Initiative activities, Ecuador developed a methane emissions country profile in 2005. This profile estimated the total GHG emissions from the farming sector using EPA's *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases* report. As shown in Figure 1.3, methane from enteric fermentation is the principal source of anthropogenic methane emissions. Wastewater, which includes both municipal and industrial wastewater, accounts for 11 percent of the emissions and manure management for 2 percent.

Figure 1.3 – Ecuador's Estimated Anthropogenic Methane Emissions by Source (2005), Total = 15.46 MMTCO$_2$e



Source: 2006 U.S. EPA Report: Global Anthropogenic Non-CO$_2$ Greenhouse Gases

2. BACKGROUND AND CRITERIA FOR SELECTION

Below is a description of the methodologies used in this RA.

2.1 METHODOLOGY USED

A variety of data sources were used for conducting the RA, including:

- **Published data**, including national and international data (e.g., United Nations Food and Agriculture Organization [FAO] animal production datasets); specific subsector information from business and technical journals; and other documents, reports, and statistics.

- **Interviews** with local experts from pertinent ministries (e.g., ministries of agriculture, environment, and energy), local non-government organizations, and engineering/consulting companies working in agriculture and rural development; current users of anaerobic digestion; and other stakeholders. The main national-level government stakeholders in Ecuador include the Ministry of Environment (MA), the Ministry of Agriculture (MAGAyP) and the Ministry of Electricity and Renewable Energy (MEER).

- **Field visits** to sites of various sizes in the different sectors to characterize the waste management systems used and to verify the information collected through other sources.

The team employed the following approach, which has been used in other RAs in this series:

Step 1: The first step in the development of the Ecuador livestock and agro-industry RA involved constructing general profiles of the individual subsectors (or commodity groups), such as dairy or swine production or sugar. Each profile includes a list of operations within the subsector and the distribution of facilities by size and geographical location. For the various commodity groups in the livestock sector, the appropriate metric for delineating distribution by size is the average annual standing population (e.g., number of lactating dairy cows or pigs). For the various commodity groups in the agro-industry sector, the metric is the mass or volume of annual processing capacity or the mass or volume of the commodity processed annually.

Step 2: Based on available data, the team then tried to determine the composition of the livestock production and agro-industry sectors at the national level, as well as the relative significance of each geographically.

Step 3: With this information, the team focused on identifying those commodity groups in each sector with the greatest potential to emit methane from waste management activities. For example, a country's livestock sector may include dairy, beef, swine, and poultry operations, but poultry production might be insignificant due to lack of demand or considerable import of poultry products, with correspondingly low methane emissions. Thus, to most effectively utilize available resources, we focused on identifying those commodity groups with higher emissions. In the best-case scenarios, these livestock production and agro-industry sector profiles were assembled from statistical information published by a government agency. If such information was unavailable or inadequate, the team used a credible secondary source, such as FAO.

Step 4: The team characterized the waste management practices utilized by the largest operations in each sector. Typically, only a small percentage of the total number of operations in each commodity group will be responsible for the majority of production and thus, the majority of the methane emissions. Additionally, the waste management practices employed by the largest producers in each commodity group should be relatively uniform. When information about waste management practices is incomplete or not readily accessible, which was often the case for the livestock sector in Ecuador. The team identified and directly contacted producer associations and local consultants and visited individual operations to obtain this information.

Step 5: The team then assessed the magnitudes of current methane emissions to identify those commodity groups that should receive further analysis. For example, in the livestock production sector, large operations in a livestock commodity group that relies primarily on a pasture-based production system will have only nominal methane emissions because manure decomposition will be primarily by aerobic microbial activity. Similarly, an agro-industry subsector with large operations that perform direct discharge of untreated wastewater to a river, lake, or ocean will not be a source of significant methane emissions. Thus, the process of estimating current methane emissions was focused on those sectors that could most effectively utilize available resources. This profiling exercise will aid in identifying the more promising candidate sectors and/or operations for technology demonstration.

2.2 ESTIMATION OF METHANE EMISSIONS IN THE LIVESTOCK AND AGRO-INDUSTRIAL SECTORS

This section describes the generally accepted methods for estimating methane emissions from livestock manures and agricultural commodity processing wastes, along with the modification of these methods to estimate the methane production potential with the addition of anaerobic digestion as a waste management system component.

2.2.1 Manure-Related Emissions

The *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Tier 2 method were used for estimating methane emissions from each commodity group in the livestock production sector. Using the Tier 2 methods, methane emissions for each livestock commodity group (M) and existing manure management system (S) and climate (k) combination are estimated as follows using Equation 2.1:

$$CH_{4\,(M)} = \left(VS_{(M)} \times H_{(M)} \times 365 \text{ days/yr}\right) \times \left[B_{o(M)} \times 0.67 \text{ kg } CH_4/m^3\ CH_4 \times MCF_{S,\,k}\right] \quad (2.1)$$

where:
- $CH_{4\,(M)}$ = Estimated methane emissions from manure for livestock category M (kg CH_4 per year)
- $VS_{(M)}$ = Average daily volatile solids excretion rate for livestock category M (kg volatile solids per animal-day)
- $H_{(M)}$ = Average number of animals in livestock category M
- $B_{o(M)}$ = Maximum methane production capacity for manure produced by livestock category M (m^3 CH_4 per kg volatile solids excreted)
- $MCF_{(S,k)}$ = Methane conversion factor for manure management system S for climate k (decimal)

As shown, Equation 2.1 requires an estimate of the average daily VS excretion rate for the livestock category under consideration. The default values for dairy cows, breeding swine, and market swine are listed in Table 2.1. Default values for other types of livestock can be found in Tables 10A-4 through 10A-9 in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table 2.1 – 2006 IPCC Volatile Solids Excretion Rate Default Values for Dairy Cows, Breeding Swine, and Market Swine (kg/head-day)

Region	Dairy Cows	Breeding Swine	Market Swine
North America	5.4	0.5	0.27
Western Europe	5.1	0.46	0.3
Eastern Europe	4.5	0.5	0.3
Oceania	3.5	0.5	0.28
Latin America	2.9	0.3	0.3
Middle East	1.9	0.3	0.3
Asia	2.8	0.3	0.3
Indian Subcontinent	2.6	0.3	0.3

Realistic estimates of methane emissions using Equation 2.1 also require identification of the appropriate MCF, which is a function of the current manure management system and climate. MCFs for various types of manure management systems for average annual ambient temperatures ranging from greater than or equal to 10°C to less than or equal to 28°C are summarized in Table 2.2, and can be found in Table 10.17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

Table 2.2 – Default MCF Values for Various Livestock Manure Management Systems

Climate	Manure Management System Default Methane Emission Factor, %								
	Lagoons	Storage Tanks & Ponds	Solid Storage	Dry Lots	Pit <1 Month	Pit >1 Month	Daily Spreading	Anaerobic Digestion	Pasture
Cool	66–73	17–25	2	1	3	17–25	0.1	0–100	1
Temperate	74–79	27–65	4	1.5	3	27–65	0.5	0–100	1.5
Warm	79–80	71–80	6	5	30	71–80	1	0–100	2

Finally, use of Equation 2.1 requires specification of the methane production potential (B_o) for the type of manure under consideration. Default values listed in Tables 10A-4 through 10A-9 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* can be used. The default values for dairy cows, breeding swine, and market swine are listed in Table 2.3.

Table 2.3 – 2006 IPCC Methane Production Potential Default Values for Dairy Cows, Breeding Swine, and Market Swine, m^3 CH_4/kg VS.

Region	Dairy Cows	Breeding Swine	Market Swine
North America	0.24	0.48	0.48
Western Europe	0.24	0.45	0.45
Eastern Europe	0.24	0.45	0.45
Oceania	0.24	0.45	0.45
Latin America	0.13	0.29	0.29

Region	Dairy Cows	Breeding Swine	Market Swine
Middle East	0.13	0.29	0.29
Asia	0.13	0.29	0.29
Indian Subcontinent	0.13	0.29	0.29

2.2.2 Agricultural Commodity Processing Waste-Related Emissions

Agricultural commodity processing can generate two sources of methane emissions: wastewater and solid organic wastes. The latter can include unprocessed raw material or material discarded after processing due to spoilage, poor quality, or other reasons. One example is the combination of wastewater and the solids removed by screening before wastewater treatment or direct disposal. These solid organic wastes may have relatively high moisture content and are commonly referred to as wet wastes. Appendix A illustrates a typical wastewater treatment unit process sequence. The methods for estimating methane emissions from wastewater and solids wastes are presented below

2.2.2.1 Wastewater

For agricultural commodity processing wastewaters, such as meat and poultry processing wastewaters from slaughterhouses, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* Tier 2 methods (Section 6.2.3.1) are an acceptable methodology for estimating methane emissions. This methodology utilizes COD and wastewater flow data. Using the Tier 2 methods, the gross methane emissions for each waste category (W) and prior treatment system and discharge pathway (S) combination should be estimated using Equation 2.2:

$$CH_{4\,(W)} = [(TOW_{(W)} - S_{(W)}) \times EF_{(W,\,S)}] - R_{(W)})] \qquad (2.2)$$

where: $CH_{4\,(W)}$ = Annual methane emissions from agricultural commodity processing waste W (kg CH_4 per year)
$TOW_{(W)}$ = Annual mass of waste W COD generated (kg per year)
$S_{(W)}$ = Annual mass of waste W COD removed as settled solids (sludge) (kg per year)
$EF_{(W,\,S)}$ = Emission factor for waste W and existing treatment system and discharge pathway S (kg CH_4 per kg COD)
$R_{(W)}$ = Mass of CH_4 recovered (kg per year)

As indicated above, the methane emission factor in Equation 2.2 is a function of the type of waste and existing treatment system and discharge pathway and is estimated using Equation 2.3:

$$EF_{(W,\,S)} = B_{o\,(W)} \times MCF_{(S)} \qquad (2.3)$$

where: $B_{o\,(W)}$ = Maximum CH_4 production capacity (kg CH_4 per kg COD)
$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway (decimal)

If country and waste-sector-specific values for B_o are not available, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* default value of 0.25 kg CH_4 per kg COD should be used. In the absence of more specific information, the appropriate MCF default value selected from Table 2.4 also should be used.

Table 2.4 – Default MCF Values for Industrial Wastewaters, Decimal

Existing Treatment System and Discharge Pathway	Comments	MCF[1]	Range
Untreated			
Sea, river, or lake discharge	Rivers with high organic loadings may turn anaerobic, which is not considered here	0.1	0–0.2
Treated			
Aerobic treatment plant	Well managed	0	0–0.1
Aerobic treatment plant	Not well managed or overloaded	0.3	0.2–0.4
Anaerobic reactor (e.g., UASB, fixed film)	No methane capture and combustion	0.8	0.8–1.0
Shallow anaerobic lagoon	Less than 2 meters deep	0.2	0–0.3
Deep anaerobic lagoon	More than 2 meters deep	0.8	0.8–1.0

[1] Based on IPCC expert judgment

If the annual mass of COD generated per year (TOW) is not known and the collection of the necessary data is not possible, the remaining option is estimation using Equation 2.4, with country-specific wastewater generation rate and COD concentration data obtained from the literature. In the absence of country-specific data, values listed in Table 2.5 can be used as default values to obtain first order estimates of methane emissions.

$$TOW_{(W)} = P_{(W)} \times W_{(W)} \times COD_{(W)} \quad (2.4)$$

where:
$P_{(W)}$ = Product production rate (metric tons per year)
$W_{(W)}$ = Wastewater generation rate (m^3 per metric ton of product)
$COD_{(W)}$ = Wastewater COD concentration (kg per m^3)

Table 2.5 – Examples of Industrial Wastewater Data

Industry	Typical Wastewater Generation Rate, m^3/metric ton	Range of Wastewater Generation Rates, m^3/metric ton	Typical COD Concentration, kg/m^3	Range of COD Concentrations, kg/m^3
Alcohol	24	16–32	11	5–22
Beer	6.3	5.0–9.0	2.9	2–7
Coffee	NA	NA	9	3–15
Dairy products	7	3–10	2.7	1.5–5.2
Fish processing	NA	8–18	2.5	—
Meat & poultry processing	13	8–18	4.1	2–7
Starch production	9	4–18	10	1.5–42
Sugar refining	NA	4–18	3.2	1–6
Vegetable oils	3.1	1.0–5.0	NA	0.5–1.2
Vegetables, fruits, and juices	20	7–35	5.0	2–10
Wine & vinegar	23	11–46	1.5	0.7–3.0

Source: Doorn et al. (1997)

2.2.2.2 Solid Wastes

A variety of methods exist for disposing the solid wastes generated during the processing of agricultural commodities. These include: 1) land application, 2) composting, 3) placement in a landfill, and 4) open burning. In addition, solid wastes from meat and poultry processing, such as solids separated from wastewater by screening and dissolved air floatation (DAF), may be disposed of by rendering.

If country and waste-sector-specific values for B_o are not available, the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* default value of 0.25 kg CH_4 per kg COD should be used. The use of this default value for the solid wastes from agricultural commodity processing is based on the assumption that the organic compounds in these wastes will degrade as rapidly as the wastewater organic fraction.

Because the mechanisms responsible for the degradation of these wastes are similar to those of livestock manure following land application, the appropriate MCF value for manure disposal by daily spreading listed in Table 10.17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* should be used. For composting, the IPCC default value of 4 g CH_4 per kg of wet waste should be used. When agricultural commodity processing wastes are disposed of in landfills, the applicable MCF depends on the type of landfill, as shown in Table 2.6.

Table 2.6 – Types of Solid Waste Landfills and MCFs

Type of Site	MCF Default Value
Managed—anaerobic[1]	1.0
Managed—semi-anaerobic[2]	0.5
Unmanaged[3]—deep (>5m waste) and/or high water table	0.8
Unmanaged[4]—shallow (<5m waste)	0.4
Uncategorized solid waste disposal sites[5]	0.6

[1] **Anaerobic managed solid waste disposal sites.** Controlled placement of waste with one or more of the following: cover material, mechanical compacting, leveling
[2] **Semi-anaerobic managed solid waste disposal sites.** Controlled placement of wastes with all of the following structures for introducing air into the waste layer: permeable cover material, leachate drainage system, pondage regulation, and gas ventilation.
[3] **Unmanaged solid waste disposal sites—deep and/or with a high water table.** All sites not meeting the criteria of managed sites with depths greater than 5 m and/or a high water table near ground level.
[4] **Unmanaged solid waste disposal sites.** All sites not meeting the criteria of managed sites with depths less than 5 m.
[5] **Uncategorized solid waste disposal sites.** Uncategorized solid waste disposal sites.

For disposal of agricultural commodity processing solid wastes by open burning, the IPCC default value of 6.5 kg of methane per metric ton of waste should be used.

For all four disposal options, the commodity-specific rate of solid waste generation must be known. In addition, information about the concentration of COD in the solid waste, on a wet weight basis, is necessary for all but the composting disposal option. However, COD concentration generally has not been used as a parameter for agricultural commodity processing solid waste characterization. The alternative is to use published values from studies of methane production potential on a volume or mass of methane produced per unit mass of wet waste, or on a VS added basis as a first-order estimate for B_o for the waste under consideration. If the COD concentration in the solid waste is known, the methane emissions resulting from land application and landfill disposal with the appropriate MCF is calculated using Equation 2.6:

$$CH_{4(SW)} = TOW_{(SW)} \times B_o \times MCF_{(SW, D)} \quad (2.6)$$

where:
- $CH_{4(SW)}$ = Annual methane emissions from agricultural commodity processing waste SW, kg CH_4 per year
- $TOW_{(SW)}$ = Annual mass of solid waste SW COD generated, kg per year
- $MCF_{(SW, D)}$ = Methane conversion factor for solid waste W and existing disposal practice S, decimal

Again, based on limited data and best professional judgment, the MCF_{AD} values of 0.90 and 0.80 appear to be reasonable estimates, respectively, for heated and ambient temperature digesters for first-order estimates of methane production potential.

2.2.2.2.1 **Leakage and Combustion Related Emissions**

The reduction in methane emissions realized when anaerobic digestion is incorporated into an existing livestock manure or agricultural commodity processing waste management system will be somewhat reduced by leakage and combustion related emissions.

There is very little information regarding methane leakage from anaerobic digestion systems although some leakage probably occurs from all systems and should be incorporated into estimates net methane emissions reductions. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories provides no guidance, with an MCF default value of 0-100 percent. Thus, the use of the 2008 California Climate Action Registry (CCAR) default collection efficiency value of 85 percent in the following equation is recommended unless a higher value can be justified by supporting documentation.

$$LK_{(P)} = \left(\frac{CH_{4\,(P)}}{0.85} - CH_{4\,(P)} \right) \times 0.67 \text{ kg/m}^3$$

where:
- $LK_{(P)}$ = project methane leakage, kg/year
- $CH_{4\,(P)}$ = estimated methane production potential from manure or agricultural commodity processing wastes or both, kg/year
- 0.85 = default methane capture efficiency, decimal

Because no combustion process is 100 percent efficient and all captured methane should be disposed of by combustion, combustion related methane emissions also should be accounted for in estimating a project's net methane emission reduction. Unless higher combustion efficiency values can be justified by supporting documentation, the default values listed in the table below should be used.

Default Values for Methane Combustion Efficiencies, decimal

Combustion Process	Default Value
Open flare	0.96
Enclosed flare	0.995
Lean burn internal combustion engine	0.936
Rich burn internal combustion engine	0.995
Boiler	0.98

Source: CCAR, 2008

Methane emissions associated with each combustion process utilized should be based on the fraction of estimated methane production that will be captured and calculated as follows:

$$CE_{(P)} = \left[\left(CH_{4\,(P)} - LK_{(P)}\right) \times \left(1 - C_{eff}\right)\right]$$

where: $CE_{(P)}$ = Combustion related emissions, kg CH_4 per year
$CH_{4\,(P)}$ = Estimated production potential, kg CH_4 per year
C_{eff} = Combustion efficiency, decimal

2.2.2.2.2 **Fossil Fuel Use Related Emissions**

An anaerobic digestion project may result in increased fossil fuel use such as use of gasoline or diesel fuel for manure transport to a centralized anaerobic digestion facility or transport of another waste to a facility for co-digestion. The resulting increase in carbon dioxide emissions also should be accounted for using the default values for fossil fuel use related carbon dioxide emission rates, as shown in the table below.

Default Values for Carbon Dioxide Factors for Gasoline and Diesel Fuel Use for Transportation

Fuel	CO2 Emission Factor, kg/L
Gasoline	2.38
Diesel	2.75

Source: Regional Greenhouse Gas Initiative, Inc, 2007

Estimate the carbon dioxide emissions resulting from increased fossil fuel use due to transportation as follows:

$$FF_{(P)} = \frac{\left(FF_{(Use)} \times C_{factor}\right)}{21}$$

where: $FF_{(P)}$ = Fossil fuel related carbon dioxide emissions on a methane equivalent basis, kg CH_4 per year
$FF_{(U)}$ = Additional fossil fuel use, L/yr
E_{factor} = Emission factor, kg CO_2/L
21 = GWP of methane as compared to carbon dioxide, kg CO_2/kg CH_4

2.3 DESCRIPTION OF SPECIFIC CRITERIA FOR DETERMINING POTENTIAL SECTORS

The specific criteria to determine methane emission reduction potential and feasibility of anaerobic digestion systems include the following:

- **Large sector/subsector:** The category is one of the major livestock production or agro-industries in the country.
- **Waste volume:** The livestock production or agro-industry generates a high volume of waste discharged to conventional anaerobic lagoons.
- **Waste strength:** The wastewater generated has a high concentration of organic compounds as measured in terms of its BOD and COD or both.
- **Geographic distribution:** There is a concentration of priority sectors in specific regions of the country, making centralized or commingling projects potentially feasible.
- **Energy intensive:** There is sufficient energy consumption to absorb the generation from recovered methane.

The top industries that meet all of the above criteria in Ecuador are palm oil processing, sugar mills, alcohol distilleries, and shrimp processing. Swine and milk production, slaughterhouses, banana processing, and milk processing sectors also were identified as possible significant sources of methane emissions, but the information gathered was not sufficient enough to characterize their waste management systems and waste volumes. Therefore, these sectors are not included as part of the main report, but information on these sectors can be found in Appendix B.

Other livestock sectors, such as beef cattle and poultry, were not considered because the methane emissions generated from those sectors are low. More information about those two sectors can be found in the study conducted with World Bank funding, titled "*Evaluación, diagnóstico y propuestas de acción para la mejora de las problemáticas ambientales y mitigación de gases de efecto invernadero vinculados a la producción porcina, avícola y bovina (feedlots y tambos)*."

The World Bank study and this RA contain similar baselines in terms of numbers of animals for the dairy and swine subsectors. However, both studies determined that comprehensive published data do not exist on how wastes are managed in the swine and dairy sectors.

2.4 EXAMPLES OF METHANE EMISSION REDUCTION PROJECTS IN ECUADOR

The use of anaerobic digesters in Ecuador is described in detail in the report "*Feasibility Study of the Use of Agriculture, Agro-industrial and Livestock Waste for Energy Production by Means of Biodigesters, MEyER*". Table 2.6 provides a summary from this report.

Table 2.6 – Anaerobic Digesters Installed in Ecuador, In Operation and Not In Operation

Project Information	PROVINCE				
	IMBABURA		SANTA ELENA	BOLÍVAR	COTOPAXI TUNGURAHUA AND CHIMBORAZO
Region	Cotacachi/18 farms of the Intag zone	Ibarra	Santa Elena/Olón	Chimbo/Guaranda	There is no registry of digesters and no information on where they are located.
Organization/Company	Fundación BRETHREN Y UNIDA - FBU	Hacienda Zuleta	Fundación Ecuatoriana Santa María del FIAT (NGO)	CORPORACIÓN CIE	TECNOSOL
Name of the Project	Promotion of the use of anaerobic digesters in integral rural farms in the zone of Intag, Cantón Cotacachi.	Unknown	Sustainable pilot project for the production of biogas and biofertilizers from wastes and wastewaters	Unknown	CODESO
Objective	Producing biogas for direct burning in kitchens and producing fertilizers for use by the farms, by means of the installation of 18 handmade anaerobic digesters, one per farm.	Promote the environmental management of livestock waste by biodigesting livestock manure and producing fertilizers for use in agriculture	Producing biogas for direct burning in kitchens and producing fertilizers for use by the farms in the project	Producing biogas for direct burning in kitchens and producing fertilizers for use by the farms, by means of the installation of 10 handmade anaerobic digesters, one per farm.	Producing biogas for direct burning in kitchens and producing fertilizers for use by the farms, by means of the installation of 10 handmade anaerobic digesters, one per farm..
Type of Waste Being Used	Mostly, swine manure, beef cattle manure in combination with wash water from the swine sector and undetermined rates of banana residues, rachis of milled banana, and diverse vegetables.	Mostly dairy cattle waste in combination with wash waters from the pens.	Human excretas and waste	Mostly swine and beef cattle manure combined with wash water from the swine sector and undetermined rates of banana residues, rachis (midribs of leaves) of milled banana and diverse vegetables.	Mostly swine and beef cattle manure combined with wash water from the swine sector and undetermined rates of banana residues, rachis of milled banana, and diverse vegetables.

Project Information	PROVINCE				
	IMBABURA		SANTA ELENA	BOLÍVAR	COTOPAXI TUNGURAHUA AND CHIMBORAZO
Installed Capacity	Wastes from 90 pigs per day (five pigs per farm). After 30 days of digestion, the composition is 22% dry matter, and assuming 0.45 m^3 of biogas/kg of dry matter, the biogas generation volume from 30 days is 1.5 m^3/day.	Plastic tanks with about 1 m^3 of capacity.	16 m^3 of wastes	Unknown	Each digester has the daily capacity to handle wastes from five pigs. .
Type of Digester	Continuous flow. Handmade tube with flexible PVC gas gauge (plastic liners of 12 m long, one inside the other and sewn). They are installed in pits of 10 m long, 1 m deep, 1 m wide, and 0.90 m in the base; being used in both warm and cold climates. They have casted concrete feedstock and discharge chamber. Expected life is 5 years.	Batch operation, each batch being a plastic tank of 1 m^3 of capacity.	Handmade, but its specific type cannot be determined because the digester has been disassembled.	Continuous flow. Handmade tube with flexible PVC gas gauge (plastic liners of 12 m long, one inside the other and sewn). They are installed in pits of 10 m long, 1 m deep, 1 m wide and 0.90 m in the base; being used in both warm and cold climates. They have casted concrete feedstock and discharge chamber. Expected life is 5 years.	Continuous flow. Handmade tube with flexible PVC gas gauge (plastic liners of 12 m long, one inside the other and sewn). Expected life is 5 years
Biogas Production	After 30 days the biogas production is continuous at 1.5 m^3/day.	Biogas production is not measured. It enters a water bottle to make bubbles.	Unknown	Approximately 1.5 m^3/day.	After 30 days, the biogas production is continuous at 1 to 2 m^3/day.

Project Information	PROVINCE				
	IMBABURA		SANTA ELENA	BOLÍVAR	COTOPAXI TUNGURAHUA AND CHIMBORAZO
Cost (USD)	Construction materials: $350/digester. The farm's owners are in charge of the labor force for building the digesters.	Approximately $100/tank.	$24,115	Approximately $400/ digester.	Unknown.
Biogas Use	In kitchens	Biogas is discarded.	In kitchens located 200 meters away from the digester.	In kitchens	In kitchens
Byproducts	Sludge with 88% moisture is used as fertilizer and the digestate is also used as fertilizer in spray.	Digestate is used as fertilizer on the farm.	None, the digester is not in operation.	Sludge with 88% moisture is used as fertilizer, and digestate is also used as fertilizer in spray.	Digestate is used as fertilizer.
Year operations began	2000	2006	2000	2004 and 2005	2000
Current status	According to the foundation director, the 18 handmade digesters are still in operation.	Batch digesters are still in operation.	The digesters are no longer in service.	According to the CIE's officer, the 18 handmade digesters are still in operation.	According to the interviewed (CODESO management), all of the digesters are out of service. This may be due to volcanic eruptions in Tungurahua.
Benefits	The use of gas in the kitchens has stopped the farmers from chopping down trees and bushes for firewood. The boil has been used as natural fertilizer. The improved management of wastes also improved the quality of the surface water.	Improved management of waste and the use of digestate as a fertilizer.	According to a representative of El Colegio, there were temporary environmental and economical benefits.	The use of gas in the kitchens has stopped the farmers from chopping down trees and bushes for firewood. The digestate has been used as natural fertilizer. The improved management of wastes also improved the quality of the surface water.	Unknown, as the project had no follow-up.

Project Information	PROVINCE				
	IMBABURA		SANTA ELENA	BOLÍVAR	COTOPAXI TUNGURAHUA AND CHIMBORAZO
Comments	The percent methane of the biogas is very low (on average 32%) while the technical literature mentions 65% yield.	Improved management of the wastes prevented them from being dumped into the surface waters and causing environmental impact.	The addition of human urine generates ammonia that inhibits bacterial activity. Also, the addition of sanitary water creates an excessive dilution of the wastes.	There was little follow-up on the operation of the digesters.	These social-community projects have not had any follow-up that would allow the benefits to be assessed.

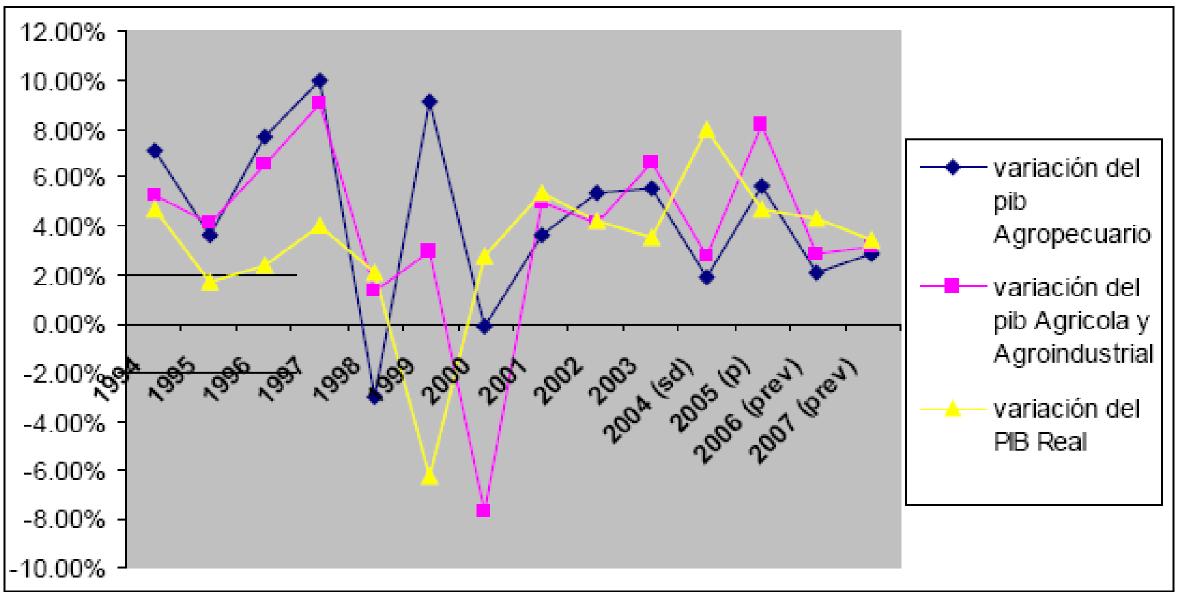
Source: Executive Summary of the *Feasibility Study of the Use of Agriculture, Agro-Industrial and Livestock Waste for Energy Production by Means of Biodigesters, MEyER*

3. SECTOR CHARACTERIZATION

3.1 INTRODUCTION

Ecuador is a predominantly agricultural country. The agricultural sector, which includes crop production, livestock, fisheries, hunting, and forestry, contributed to nearly 10.28 percent of the national real gross domestic product (GDP) of Ecuador in the past decade. Taking into account agro-industrial activities, the average contribution of all agricultural activities amounts to 17.52 percent of the real GDP (IDB, 2008). The variation of the agriculture and agro-industrial GDP is shown in Figure 3.1.

Figure 3.1 – Agricultural and Agro-Industrial GDP Variation



Fuente: Cuentas Nacionales del Banco Central del Ecuador.

Variation of the agricultural and livestock GDP
Variation of the agricultural and agro-industrial GDP
Variation of the real GDP

According to provisional data from Central Bank of Ecuador (BCE) for 2007, the value added of agriculture and agro-industrial activities to Ecuador's economy is presented in Table 3.1. Each sector's contribution to the GDP is presented as a percent of the total GDP.

Table 3.1 – Value Added of Agriculture and Agro-Industrial, as Percent of GDP

Sector	GDP
Agriculture and forestry	8.9
Cereal crops	2.6
Flower growing	0.9
Other crops	1.5
Animal raising	1.3

Sector	GDP
Banana, coffee, and cocoa cultivation	1.7
Forestry and wood	1.0
Fisheries	1.7
Shrimp raising	0.8
Fishery	0.9
Agro-industry	7.8
Production, processing, and conservation of meat and meat products	1.1
Shrimp processing	2.6
Processing of fish and fish products	1.1
Processing of oils and fats of vegetable and animal origin	0.3
Processing of dairy products	0.5
Processing of milling and bakery products	0.4
Sugar processing	0.5
Processing of cocoa, chocolate, and candy products	0.2
Processing of other food products	0.5
Beverage processing	0.5

Source: BCE

According to the Third Annual Census of Agriculture (III CNA), the land surface devoted to agriculture and livestock production is approximately 12,654 hectares (Ha), divided into about 843 units of agricultural production (UPAs). UPAs are the units used in the national agricultural census, and they correspond to a land surface of 500 m² or more that is completely or partially dedicated to agricultural production. Land areas of less than 500 m² may be considered a UPA if they sold a product during the period of reference. Each UPA is considered an economic unit (i.e., developing an economic activity under a single management system).

Livestock production in Ecuador has progressively increased over time. According to the III CNA, there are more than 4,487,000 head of meat and dairy cattle; more than half of which are native breeds. Meat production is mainly concentrated on the coast (75 percent), and milk production is mainly concentrated in the Sierra Mountains (73 percent). There are more than 1 million swine, nearly two-thirds of which are concentrated in the Sierra Mountains. The poultry sector consists of 41,157,498 birds, with nearly 80 percent of the birds being raised in confined facilities.

Ecuador is an important exporter of bananas (Ecuador is the world's largest banana producer and exporter), flowers, and cocoa (eighth global producer). Ecuador's shrimp production is also significant, as well as its production of sugar, rice, cotton, maize, palm hearts, and coffee.

The country is divided into three natural regions that are clearly defined by their topography, climate, vegetation, and population: the Coastal region in the west, the mountainous region (or Sierra) in the center and the Eastern region. The Archipelago of Colón or Galápagos Islands are 600 miles to the west of the equatorial coast. These islands are a group of several islands, La Isabela being the largest.

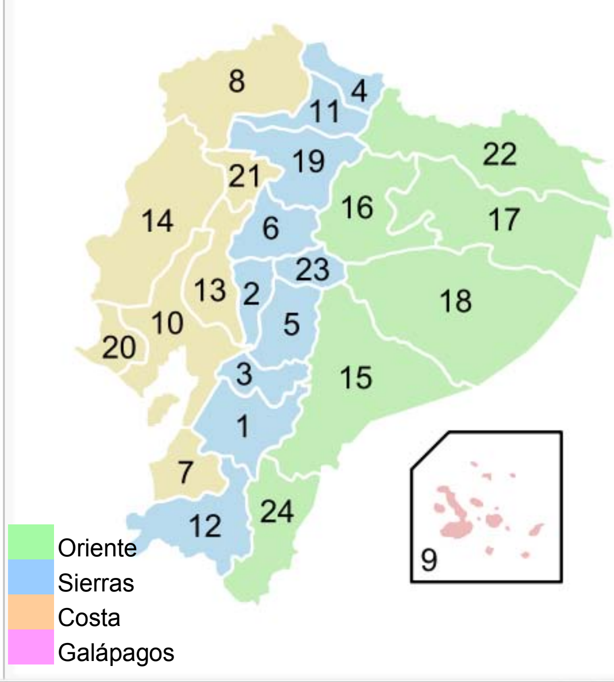
The Coastal or Littoral region has generally low elevations, not exceeding 800 meters above sea level. The main mountain system of the region comprises the Coastal mountain chain of Chongón or Colonche that divides it in two subregions called External Coastal and Internal Coastal.

The Sierra region is intersected by the Andes, which pass through from north to south. The mountain chain is divided into two parallel systems: Cordillera Oriental and Occidental, separated by a longitudinal plain divided in several valleys by crossed knots, with altitudes ranging from 1,200 to 6,000 meters above sea level.

The Eastern region extends from the Eastern foothills of the Central mountain chain of the Andes up to the borders with Peru in the east, and from the borders with Colombia up to the borders with Peru in the south. This region has tropical characteristics with plains that have not been widely explored.

All regions of Ecuador, depicted in Figure 3.2, have agriculture and livestock production. The Coastal and Sierra regions have the greatest production.

Figure 3.2 – Regions of Ecuador



#	Provincia	Capital
1	Azuay	Cuenca
2	Bolivar	Guaranda
3	Cañar	Azogues
4	Carchi	Tulcán
5	Chimborazo	Riobamba
6	Cotopaxi	Latacunga
7	El Oro	Machala
8	Esmeraldas	Ciudad Esmeraldas
9	Galápagos	Puerto Baquerizo Moreno
10	Guayas	Guayaquil
11	Imbabura	Ibarra
12	Loja	Loja
13	Los Ríos	Babahoyo
14	Manabí	Portoviejo
15	Morona Santiago	Macas
16	Napo	Tena
17	Orellana	Francisco de Orellana
18	Pastaza	Puyo
19	Pichincha	Quito
20	Santa Elena	Santa Elena
21	Santo Domingo de los Tsáchilas	Santo Domingo
22	Sucumbíos	Nueva Loja
23	Tungurahua	Ambato
24	Zamora Chinchipe	Zamora

Source: Prepared by the authors

3.2 SUBSECTORS WITH POTENTIAL FOR METHANE EMISSION REDUCTION

As discussed in Section 2.1, the following two criteria were used to rank sectors: 1) the sector or subsector size and 2) the geographic concentration (particularly for anaerobic digestion centralized systems).

The important subsectors of the livestock production and agricultural commodity processing sectors in Ecuador, as identified in this RA, are summarized in Table 3.2. These sectors include swine, dairy, and banana farms; oil and shrimp processing facilities; slaughterhouses; sugar mills; and alcohol distilleries. The sectors are largely located in the Coast and Sierra regions.

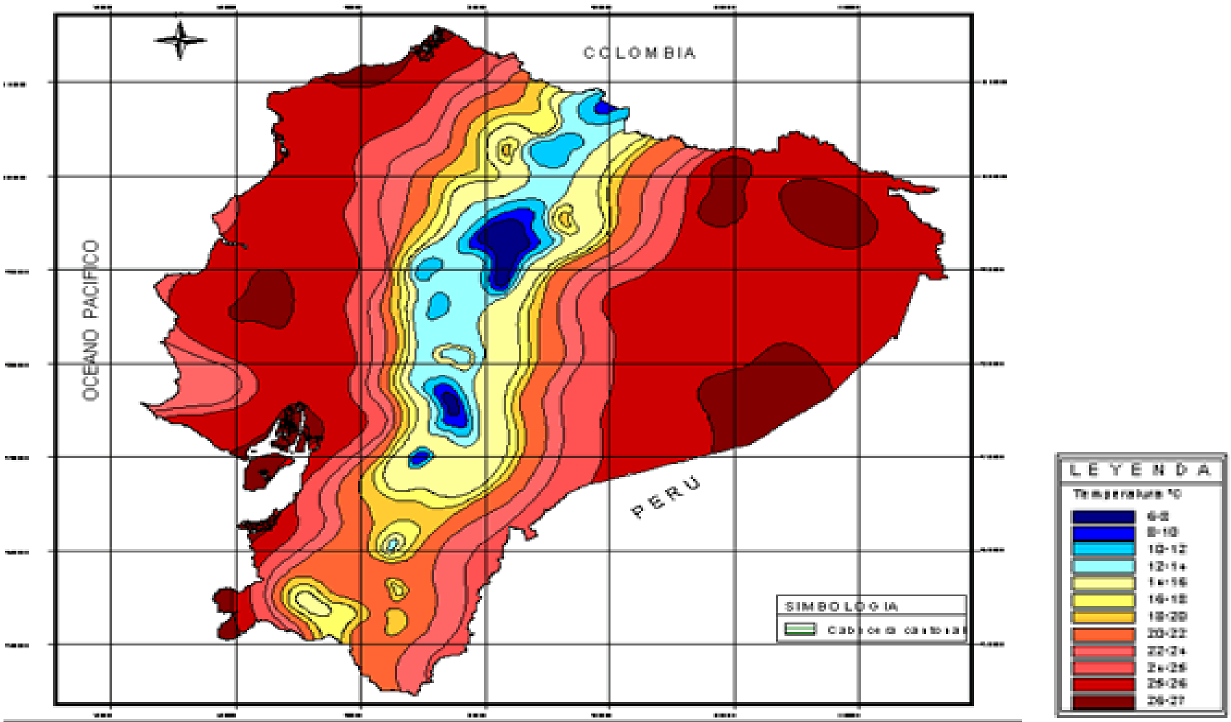
Table 3.2 – Main Subsectors with Potential for Methane Emission Reduction

Subsector	Size	Geographical Distribution
Swine	1,097,000 pigs in 2008	Sierra region: Pichincha, Cotopaxi, Loja and Chimborazo Coast region: Manabí and Guayas
Dairies	971,000 milking cows in 2008 5,325,653 liters of milk in 2008	Sierra region: Pichincha, Azuay, Cotopaxi Coast region: Manabí
Palm oil processing	220,000 hectares sown in 2008 415,000 MT raw oil in 2008	Coast region: Santo Domingo, Esmeraldas East region
Banana farms	6,300 farms, 233,000 hectares planted, 6,700,000 MT produced in 2008	Coast region: Los Ríos, El Oro, Guayas
Slaughterhouses	771,000 bovines and 471,000 pigs slaughtered in 2005	Sierra region: Pichincha Coast region: Guayas
Sugar mills	5,000,000 MT of processed cane, 10,500,000 50 kilogram-sacks of sugar produced in 2006 from 6 refineries	Coast region: Guayas, Cañar, Los Ríos
Alcohol distilleries	3 distilleries producing 146,000 liters/day in 2005	Coast region: Guayas, Cañar, Los Ríos
Shrimp processing	295,000,000 pounds of shrimp exported in 2008 from 61 processing plants	Coast region: mainly Guayas

A more detailed discussion of the palm oil processing, sugar mills, sugar mills with alcohol production, and shrimp processing subsectors is provided in Sections 3.3 through 3.6. Due to limited available data, detailed discussions were not developed for the swine, dairy, and banana farm sectors; however, more information on these sectors is presented in Appendix B.

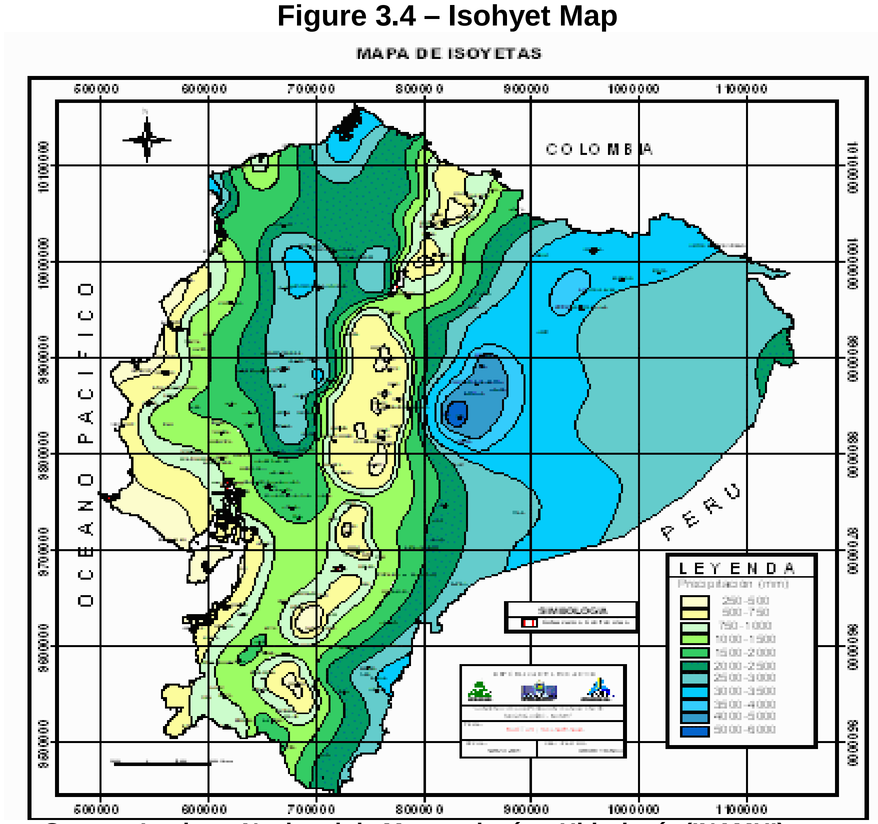
Because methane production is temperature-dependant, an important consideration in evaluating locations for potential methane capture is the temperature. In Ecuador, the annual average temperature ranges between 6° C and 27° C. Figure 3.3 depicts a multi-annual isotherm temperature map for the country, while Figure 3.4 shows an isohyet precipitation map.

Figure 3.3 – Multi-Annual Isotherm Map



Source: Instituto Nacional de Meteorología e Hidrología (INAMHI)

Figure 3.4 – Isohyet Map



Source: Instituto Nacional de Meteorología e Hidrología (INAMHI)

Due to the presence of the Andes and the ocean influence, Ecuador's climate varies from region to region. Further, due to its tropical location, each climate zone has only two defined seasons: wet and dry. In both the Coast region (which has palm oil extractors, refineries and distilleries, swine farms, shrimp processing plants) and the East region (which has palm oil extractors), temperature ranges between 20 C and 33 C, while in the Sierra region (which has swine and dairy farms), it is usually between 8 C and 23 C. The wet season extends from December to May in the Coast region, between November and April in the Sierra region, and from January to September in the East region. Galápagos has a mild climate with temperature ranges between 22°C and 32°C.

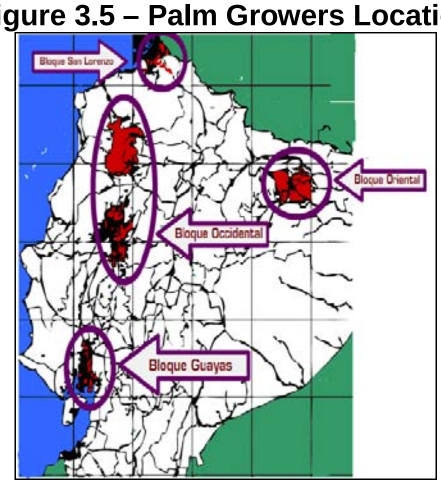
3.1.2 Palm Oil Processing Plants

a. DESCRIPTION OF SIZE, SCALE OF OPERATIONS, AND GEOGRAPHIC LOCATION

Ecuador is the sixth largest producer of palm oil globally, with 220,000 Ha sown, a production of 415,000 MT of raw oil in 2008, and a production estimate by the National Association of Oil Palm Cultivators (ANCUPA) for 2009 of nearly 445,000 MT.

African palm is the most prevalent type of palm in Ecuador. The sowing of African palm in Ecuador is located in four main areas, as seen in Figure 3.5. These areas include West, East, San Lorenzo, and Guayas.

Figure 3.5 – Palm Growers Location



Source: FEDAPAL

In Ecuador, there are 48 facilities devoted to the processing of palm oil, with an installed capacity of 567 metric tons of fresh fruit per hour (TFF/H), from which 20 percent of raw palm oil is extracted. For every five metric tons of fresh fruit processed, 1 metric ton of raw palm oil is obtained.

The 48 extracting plants are located as follows: 40 in the West, three in the East, two in Guayas, and three in San Lorenzo, as seen in Table 3.3.

Table 3.3 – Palm Oil Extracting Plants

Area	Extracting Plant	Plant Capacity TFF/H	Status	Area Capacity TFF/H
West	Aceitplacer	9	Operational	393
	Agrícola La Concordia	6	Operational	
	Agroaceites	9	Operational	
	Agroparaíso	10	Operational	
	Agrosexta	12	Operational	
	Alespalma	10	Operational	
	Alzamora Cordovez (Teobroma)	15	Operational	
	Atahualpa	6	Operational	
	Danayma	12	Operational	
	Epacem 1	9	Operational	
	Epacem 2	6	Operational	
	Extrazur (Etesa)	9	Operational	
	Inexpal	9	Operational	
	La Joya	9	Operational	
	Oleocastillo	9	Operational	
	Oleorios	9	Operational	
	Palciem	25	Operational	
	Palduana	20	Operational	
	Palmera de Los Andes (Quininde) *	32	Operational	
	Palmex	9	Operational	
	Palmisa	13	Operational	
	Pexa	16	Operational	
	Provasa	7	Operational	
	Quevelpalma	22	Operational	
	Río Manso *	10	Operational	
	Roblama	7	Operational	
	San Carlos	18	Operational	
	San Daniel	9	Operational	
	Sopalin	19	Operational	
	Sozoranga	6	Operational	
	Tarragona	9	Operational	
	Unipal	18	Operational	
	Viche	4	Operational	
	Hacienda La Palma	15	Not in operation	
	La Merced	3	Not in operation	
	Nápoles	6	Not in operation	
	Oleaginosas del Ecuador (Fabril)	9	Not in operation	
	Palmagro	12	Not in operation	
	Palnorec	3	Not in operation	
	El rocío	6	Unknown	
East	Palmar del Río	32	Operational	70
	Palmeras del Ecuador *	32	Operational	

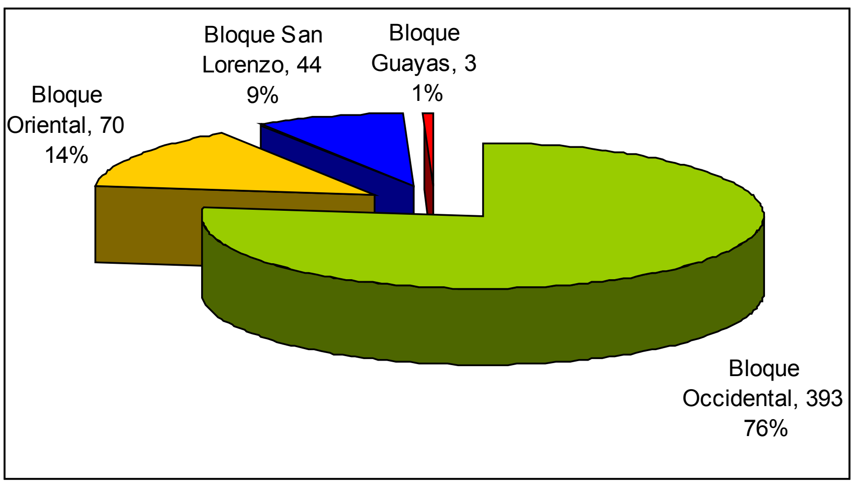
Area	Extracting Plant	Plant Capacity TFF/H	Status	Area Capacity TFF/H
	Pamela	6	Operational	
San Lorenzo	Aiquisa	12	Operational	44
	Palesema	12	Operational	
	Palmeras de Los Andes (San Lorenzo)	20	Operational	
Guayas	Olitrasa	3	Operational	3
	La Juana	3	No information	

Source: ANCUPA – FEDAPAL

Regarding operating conditions, as can be seen in Table 3.3, there are 33 plants in operation (out of 40 total plants) in the West. All plants in the East and in San Lorenzo are operational, and one plant in Guayas is operational. Only operational plants were included in the capacity estimate per area.

As seen in Table 3.3 and Figure 3.6, the largest palm oil extraction capacities are in the West, with 393 TFF/H representing 76 percent of the total production. The East has the second largest palm oil extraction capacity, with 70 TFF/H and 14 percent of the total production.

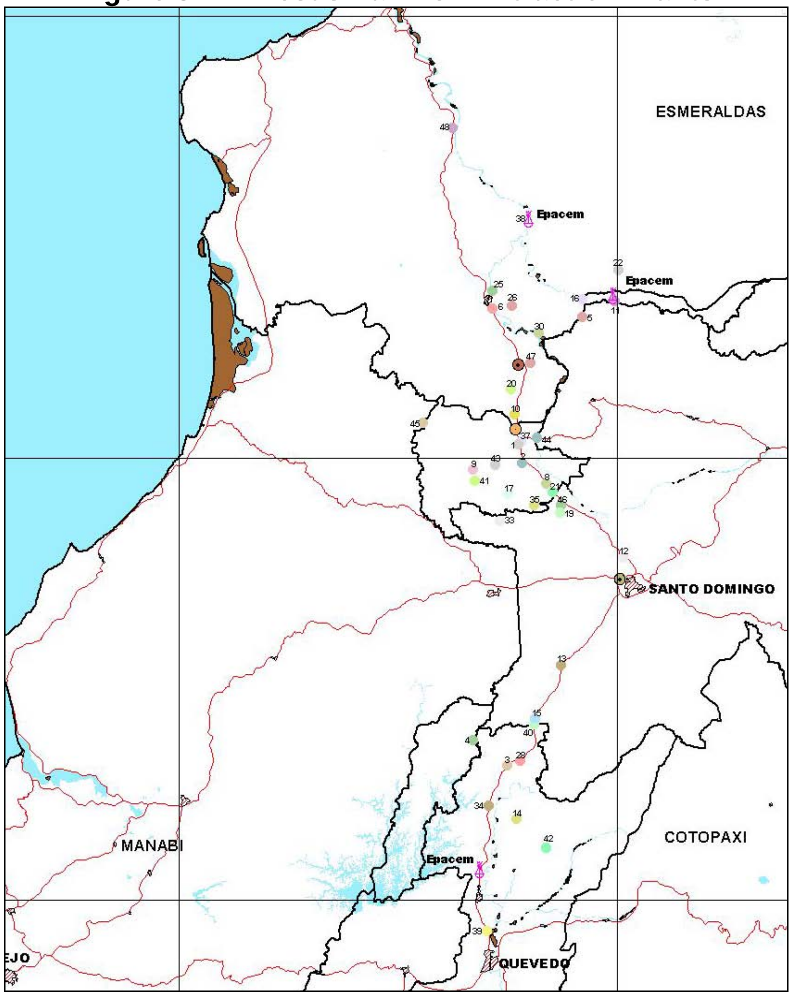
Figure 3.6 – Palm Oil Extraction Capacity Per Area



Source: ANCUPA

Figure 3.7 shows the location of the West's palm oil extraction plants.

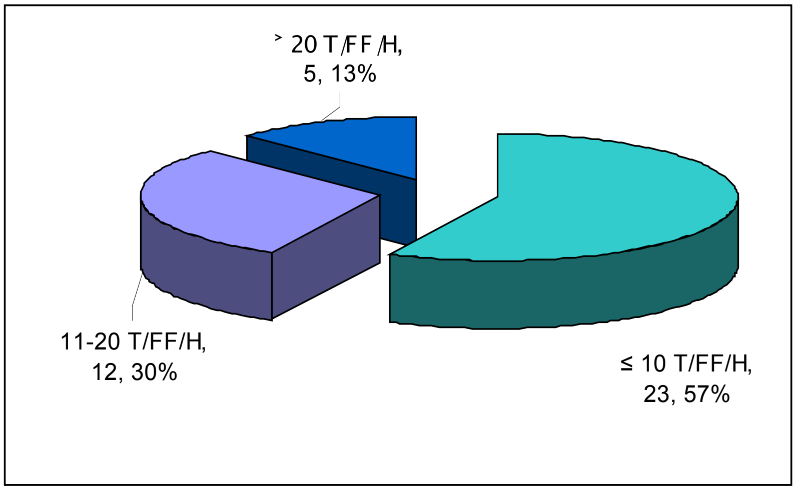
Figure 3.7 – West's Palm Oil Extraction Plants



Source: ANCUPA, National Palm Census, 2005

The palm oil plant distribution per size category is presented in Figure 3.8. There are 23 plants in operation, with a capacity equal to or less than 10 TFF/H, which represents 57 percent of all plants. There are 12 extracting plants that can produce between 10 and 20 TFF/H (30 percent of all plants) and five plants with a capacity over 20 TFF/H (13 percent of all plants).

Figure 3.8 – Stratification of Palm Oil Extraction Plants Per Size Category



Source: ANCUPA

In the extraction process the following products and byproducts are generated: raw oil, palm kernel cake, rachis, fiber, nuts, fibrous "cachaza," and 600 kg effluent per 1000 kg of oil.

The palm oil production may vary during the year; in the winter months or rainy season, which lasts about 5 months, production may be significantly less (less than half) of the production during the dry season.

b. DESCRIPTION OF WASTE CHARACTERISTICS, HANDLING, AND MANAGEMENT

Liquid residues coming from African palm processing are oily compounds containing solids in suspension and a high content of organic matter. According to the information gathered from the field visits and data from ANCUPA, the wastewater from more than 90 percent of the palm oil extracting plants is treated in oxidation lagoons.

Depending on the particular characteristics of each establishment, BOD values are in the range of 20,000 to 40,000 ppm, and COD values are between 40,000 and 70,000 ppm.

Case studies of three palm oil processing plants (Agroparaiso, Danayma, and Epacem 2) are presented below. This information was obtained from site visits and/or published reports.

Agroparaíso (Source: Visit to the plant and published environmental impact assessment [EIA])

Agroparaíso, located in the Province of Santo Domingo de los Tsáchilas, has a production capacity of 10 TFF/H, processing 400 MT/day and 80,000 MT/year.

Effluent generation is around 190 to 210 Liters/MT, generating nearly 120 m^3 of wastewater which is directed to the lagoons at an initial temperature of 70°C. The treatment system is composed of five lagoons, all sized at 15 m x 50 m x 2 m with a total capacity of 15,800 m^3.

The wastewater characteristics before treatment are BOD 23,000 ppm and COD 40,000 ppm and after treatment BOD 4,100 ppm and COD 4,580 ppm.

Danayma (Source: Publication DANAYMA – Methane recovery from palm oil industry. November 2005)
Danayma, located in the Province of Esmeraldas, has a production capacity of 12 MTFF/H, generating 48,000 m^3/year of wastewater. The effluent is treated in a lagoon system with the following process: 2 months in the first anaerobic lagoon with a capacity of 8,541 m^3, followed by continued anaerobic process in the second lagoon with a capacity of 7,680 m^3, and then treatment third lagoon with a capacity of 8,064 m^3. Treatment in the third lagoon is primarily aerobic; however, there is evidence of anaerobic destruction. After 6 months, wastewaters are pumped into the palm plantation surroundings, where they are used for irrigation. The wastewaters in Danayma have the following characteristics:

Parameter	Concentration Before Treatment	Concentration After Treatment
BOD	25,000 to 30,000 mg/l	2,800 mg/l
COD	45,000 to 55,000 mg/l	4,500 mg/l
Suspended material	45,000 to 50,000 mg/l	--
pH	4.3	--

The facility has a total of seven treatment lagoons (although only three are being used) with a total capacity of 38,000 m^3. The goal is to use the complete system, capturing all of the methane generated in the anaerobic lagoons.

Epacem 2 (Source: Draft EIA Expost, January 2009)

The extracting plant Epacem 2, located in Km. 26 of Vía Quevedo, carries out extraction of oil from African palm with a process capacity of 20 MT/hr of fruit. The annual average production is about 6,800 MT/year of palm oil and 3,740 MT/year of palm kernel.

Raw material used in the process is composed of 34,000 MT/year of African palm fruit, 3,740 MT/year of palm nuts, and 25,500 MT/year of water, with the latter provided from a well and a creek with an average volume of 31,730 m^3/year.

The extracting plant consumes 405,751 kW/month of power through the area's distribution grid and 4,000 gal/year of diesel.

The effluent is an oily liquid with organic matter and

Lagoon 1: Hydrolytic-Acidogenic, Vol. 800m^3, Time 5d

<table>
<tr><th colspan="2">Epacem 2 (Source: Draft EIA Expost, January 2009)</th></tr>
<tr><td>solid particulate, generated in the physical sterilization process with a volume of 0.12 m^3/MT of Fresh Fruit Bunch (FFB), in clarification with an average of 0.53 m^3/MT FFB and in the boiler purges. The flow going into the oxidation lagoons is 70 m^3/d.

The composition of the effluent is:
• pH 4.5
• Temperature 60°C
• COD 70,000 ppm
• BOD 40,000 ppm
• Oil 9,000 ppm
• Total solids 35,000 ppm
• Solids in suspension 25,000 ppm
• Acidity 1,600 ppm
• Volatile fatty acids 3,000 ppm

For the treatment of wastewater, there is a primary process consisting of the physical separation of fats, followed by a secondary microbiological treatment using four lagoons using the anaerobic, facultative, and aerobic digestion degradation process.</td><td>Lagoon 2: Acetogenic, Time 30d

Lagoon 3: Methanogenic, Vol. 5,573m³, Time 35d

Lagoon 4: Methanogenic, Vol. 5,573 m³, Time 35d
</td></tr>
</table>

3.1.3 Sugar Mills

a. DESCRIPTION OF SIZE, SCALE OF OPERATIONS, AND GEOGRAPHIC LOCATION

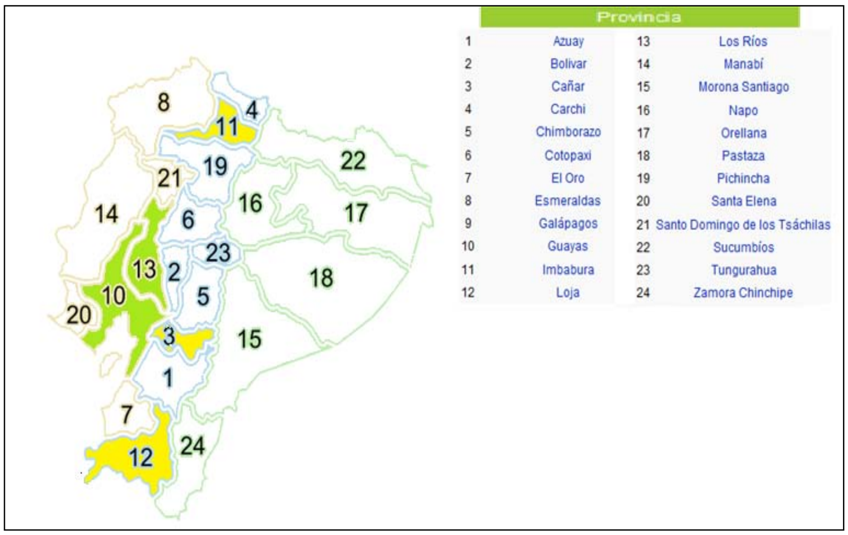
Sugar production is an important component of the Ecuadorian economy, being one of the most important agro-industries of the country. According to the information published by CINCAE, sugarcane's production area in Ecuador is about 110,000 Ha, most of which is used for sugar manufacturing and the remainder for production of “panela” (compact brown sugar) and alcohol.

In 2006, the harvested surface for sugar production was 69,156 Ha, with 89 percent of the land concentrated in the Lower Basin of Guayas River (Provinces of Guayas, Cañar, and Los

Ríos), where the refineries with largest production are located: Ecudos, San Carlos, and Valdez. The remaining 11 percent corresponds to IANCEM refineries, in the province of Imbabura, and Monterrey in the province of Loja. Sugarcane acreage has significantly increased over the past years (48,201 Ha in 1990 to 69,156 Ha in 2006). This increase may be accentuated in future years due to the expected use of ethanol as fuel.

Figure 3.9 shows the main sugarcane producing provinces in the Lower Basin of Guayas and in the Sierra.

Figure 3.9 – Sugarcane Producer Provinces



Source: MAGAyP

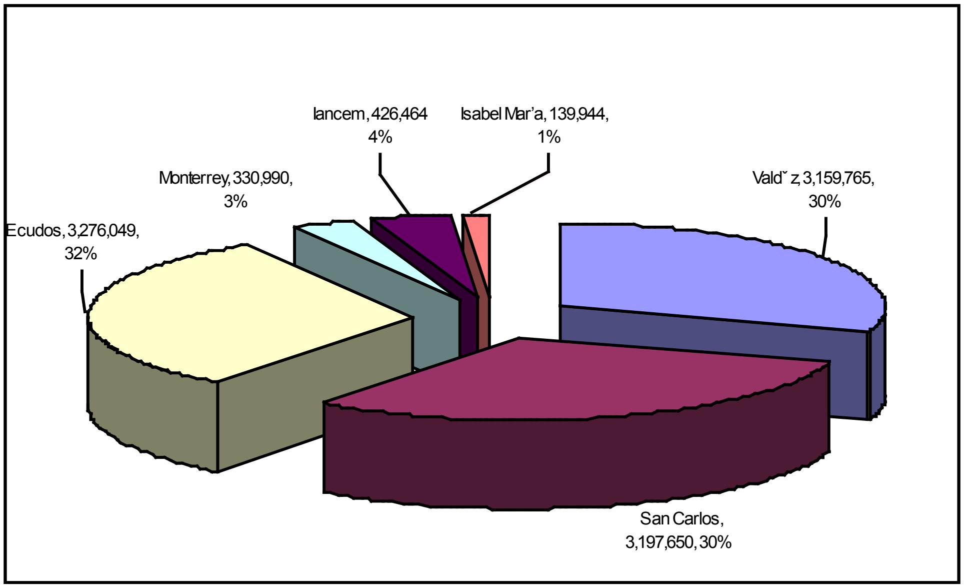
Table 3.4 and Figure 3.10 show the size of each of the refineries during 2005–2006.

Table 3.4 – Total Hectares and Harvest Production 2005–2006

Refineries	Total Hectares		Sugarcane Production		
	Sown	Harvested	Sugarcane per hectare, MT/Ha	Total Sugarcane, MT	50 kg Sacks
Valdéz	20,100	19,312	75	1,368,608	3,159,765
San Carlos	22,500	21,344	79	1,666,856	3,197,650
Ecudos (La Toncal)	24,800	22,200	78	1,541,246	3,276,049
Monterrey	2,200	2,200	85	187,000	330,990
Lancem	3,300	2,924	82	240,940	426,464
Isabel María	1,200	1,176	75	82,320	139,944
Total	74,100	69,156		5,086,970	10,530,862

Source: CINCAE

Figure 3.10 – Size of Refineries in 2005–2006, Production of 50 kg Sugar Sacks



Source: CINCAE

The refineries Ecudos, San Carlos, Valdéz, and Isabel María, located in the Lower Basin of Guayas River, start harvesting in July and continue until December, with 24-hour milling processes in three shifts and an inter-harvesting time (exclusively directed to machinery maintenance) between January and June. In the refineries Lancem and Monterrey, located in the Sierra region, sugar is harvested and produced all year long, with plants working six days a week and the inter-harvesting time taken between January and February.

The sugar produced in Ecuador is basically for domestic consumption. Since 2005, the three largest refineries have begun programs of electric power co-generation, using the bagasse from the plants. Alcohol processing plants have been established for the pharmaceutical and alcohol beverages industries, with plans to develop ethanol processing for fuel.

b. DESCRIPTION OF WASTE CHARACTERISTICS, HANDLING, AND MANAGEMENT

The wastes generated during sugarcane processing include:

- **Wastewaters:** The combined effluents of milling, refining, and cooling processes. On average, 10 m^3 of wastewaters are generated per each metric ton of sugarcane, but it can be substantially reduced with the partial recycling and reuse of some streams of the plants waters.

- **Cachaza:** The solid residue of the sugarcane juice filtrate, after clarification. It has 40 percent moisture. About 4 percent of the processed sugarcane is generated as such; that is, 40 kg/MT of sugarcane. It is a spongy, amorphous material of dark color that absorbs great amounts of water. It is generally rich in phosphorus, calcium, and nitrogen.

- **Particulate material from chimneys:** Generated by the bagasse combustion (remaining fiber after juice extraction) and other fuels in boilers without any gas treatment devices.

Depending on the source and process stage, Table 3.5 identifies the residues and byproducts generated.

Table 3.5 – Residues and Byproducts Generated in Process Stages

Source	Process Stage	Residues/Byproducts
Sugarcane	Harvesting	Ashes and gases by burning.
Sugarcane	Milling	Wastewaters from sugarcane washing, floor washing, and oils from lubrication systems. Bagasse is a byproduct, containing 50 percent moisture, and it is sent to boilers where it is burned as fuel.
Cane juice	Process	Washwaters from floors and from different components, such as evaporators, heaters, and containers. Cachaza is produced as filtration residue and molasses as a byproduct.
Bagasse	Boilers	Smoke, gases, and particulate material from chimneys; ashes from combustion chambers; and wastewaters from scrubbers.
Water and chemicals	Cooling lagoon	Wastewaters.

Sugar refineries in Ecuador have sedimentation lagoons for separating solids, soil, and plant material from the water used in sugarcane washing. Solids are returned to the field while the water is recycled and used again in sugarcane washing.

Specific information about the Refinery Valdéz is provided below.

Refinery Valdéz (Source: Field visit)

Located in Milagro, Guayas, in 2008 it processed 1,433,157 MT of sugarcane, with a production of 3,016,564 of 50-kg packs of refined sugar.

It generates 51.49 m^3/MT of wastewaters, nearly 45,292 m^3/d, during the six production months

COD: 2,752 ppm

BOD: 1,450 ppm

Wastewaters, at 35–56°C, are directed to a system of anaerobic lagoons and then used to irrigate cane crops.

Bagasse is used as fuel; ashes are taken to the lagoons.

Picture 1: Sugar mill effluent entering the lagoon system

Picture 2: Another view of the lagoon system

Picture 3: Another view of the lagoon system

3.1.4 Alcohol Distilleries

a. DESCRIPTION OF SIZE, SCALE OF OPERATIONS, AND GEOGRAPHIC LOCATION

The installed capacity of the alcohol producer sector is estimated at 160,000 L/day, or 47,107,000 L/year (assuming a reasonable efficiency rate and number of work days in the year). The total production in 2005 included a sale of 49,636,632 L of alcohol with an average production of 145,990 L/day.

The alcohol producing plants in Ecuador are described in Table 3.6.

Table 3.6 – Alcohol Distilleries, Location and Capacity

Plant	Location	Capacity	Product
Codana	Milagro, Pcia. Guayas, 45 km from Guayaquil, near Ingenio Valdez	12,000,000 L/year	Ethyl Alcohol Extra Neutral of 96° G.L
Soderal	Marcelino Maridueña, Pcia. Guayas, 67 km. from Guayaquil, near Ingenio San Carlos	32,000 L/day	Ethyl Alcohol Extra Neutral of 96° G.L, Ethanol Anhydride of 99.7° G.L using molecular filter system
Producargo	La Troncal, Cañar, 72 km from Guayaquil, near Ingenio Ecudos, La Troncal	90,000 L/day	Alcohol extra neutral, industrial alcohol (normal rectified), alcohol anhydride, deodorized alcohol for perfumes, fresh rum, or rum tafias

b. DESCRIPTION OF WASTE CHARACTERISTICS, HANDLING, AND MANAGEMENT

The main distillery residue is vinasse, a liquid effluent with BOD and COD concentrations of 40 g/L and 100 g/L, respectively. Approximately 12 to15 L of vinasse is produced per liter of alcohol produced (or 120 L per MT of sugarcane produced). If refineries produce alcohol directly from sugarcane juice, the rate of vinasse production increases to 1,020 L/MT of sugarcane produced. In addition, distilleries generate wastewater from cleaning of plant equipment.

According to the information gathered during the trip in Ecuador, the country's alcohol distilleries have lagoons for the treatment of the liquid effluents. Specific information on Distillery Codana, visited during the trip, is presented below.

<table>
<tr><th colspan="2">Distillery Codana (Source: Field visit)</th></tr>
<tr><td>Production: 12,000,000 L/yr, including refined alcohol and anhydride

Wastewaters: 12 to 14 L vinasse/L produced alcohol, 144,000,000 L vinasse/yr

Average temperature of effluent is 80°C

COD: 70,000 ppm

BOD: 25,000 ppm

Treatment process: lagoons, anaerobic reactor</td><td>Picture 1: Distillery slops entering lagoon #1
</td></tr>
</table>

	Picture 2: View of Lagoon #1  Picture 3: View of UASB system (not operating) 

3.1.5 Shrimp Processing

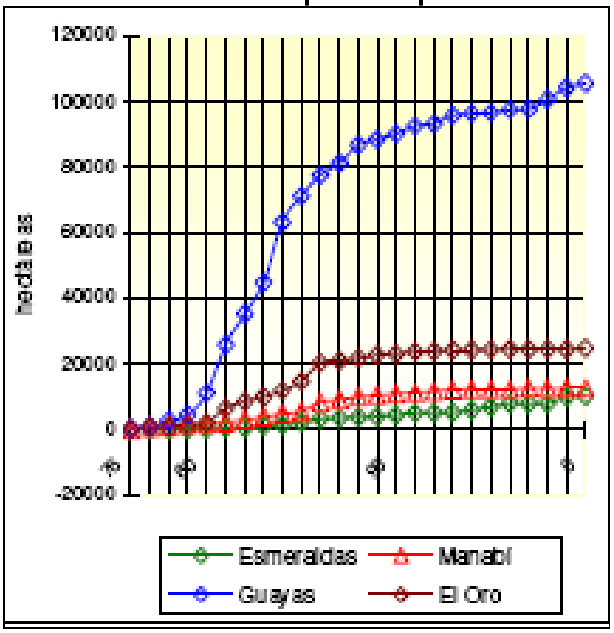
a. DESCRIPTION OF SIZE, SCALE OF OPERATIONS, AND GEOGRAPHIC LOCATION

Ecuador started growing shrimp in pools in the 1970s. During the 1980s, shrimp production became a main contributor to the Ecuadorian economy and is now one of the three highest incomes generated in the country.

Approximately 90 percent of the shrimp produced in Ecuador are grown in pools, with the remainder coming from the Pacific Ocean. Weather conditions contribute to the product's continuous supply, and harvests range between 2 and 2.8 times per year.

According to the Planning Program of Fishery and Aquaculture of Ecuador (POPAE), in 2000, shrimp growing used more than 140,000 Ha of pools, and there were more than 2,000 producers. Most of the pools were located in the province of Guayas. Figure 3.11 illustrates the evolution of shrimp growing over time.

Figure 3.11 – Hectares of Shrimp Pools per Province 1976–2000



Source: POPAE, DGP, 2003

Ecuador's shrimp production suffered for several years in the early 2000s due to the presence of white spot virus. Shrimp production has been returning to previous levels since 2005.

Shrimp obtained during farming and fishing are taken to the shrimp processing plants (packaging companies), which focus on export. According to the General Directorate of Fisheries (DGP), in 1999, some 78 processing plants exported about 20 types of products. The main products were Individually Quick Frozen (IQF) whole shrimps or tails in boxes, bags, or blocks covered in breadcrumbs with special flavors. The United States was the main market for these products.

In 2003, DGP had registered 51 packaging companies of frozen shrimp for exportation but did not have information regarding the installed capacity of the plants. Regarding their location, DGP registered 38 in Guayaquil-E.Alfaro (Durán), six in Manta-via Portoviejo, four in Bahía de Caráquez-Chone, and three in Machala-Pto. Bolívar.

Table 3.7 shows the evolution of shrimp exportations from 1994 to 2008 in pounds and dollars.

Table 3.7 – Shrimp Exportations, 1994–2008

Year	Exportations	
	Pounds	Dollars (US)
1994	156,200,837	$514,300,354.88
1995	190,862,764	$665,174,329.74

Year	Exportations	
	Pounds	Dollars (US)
1996	188,541,533	$615,307,841.99
1997	240,004,270	$871,664,843.90
1998	252,985,907	$875,050,894.01
1999	209,040,500	$616,942,114.94
2000	82,955,793	$297,408,403.40
2001	99,801,296	$280,694,073.08
2002	103,033,746	$263,859,174.42
2003	126,750,834	$303,820,895.88
2004	158,460,630	$350,147,733.06
2005	212,575,213	$480,251,487.00
2006	264,361,763	$597,670,743.40
2007	273,137,769	$582,028,512.15
2008	294,733,588	$673,469,146.78

Source: CNA, 2009

Most shrimp packaging companies are located in Guayaquil and its surroundings. There are 18 plants that are the most recognized at the national level, with Expalsa, Songa, Omarsa, and Promarisco being the main ones. A list of the shrimp processing companies is provided in Table 3.8 below.

Table 3.8 – Shrimp Processing Companies with Exports in 2007

Shrimp Processing Companies of Ecuador		
Agrol	Frigolandia	Oceanpro
Alquimia Marina	Gambas Del Pacifico	Omarsa
Awardcorp	Gondi	Pacfish
Bilbosa	Hector Marty Canino	Pcc Congelados Frescos
Braistar	Inepexa	Peslasa
Calvi	Jorge Gino Cristiansen	Pesquera Cristiansen
Camaronera Jenn Briann	Jorge Luis Benitez Lopez	Pisacua
Criaderos De Mariscos	Karpicorp	Proculmar
Damco	Langosmar	Produmar
Dufer	Maersk Ecuador	Promarisco
Dumary	Mardex	Propemar
Dunci	Marecuador	Proriosa
Edpacif	Marines	Sea Pronto

Shrimp Processing Companies of Ecuador		
El Rosario	Natural Select	Songa
Empagran	Navecuador	Sta. Priscila
Emprede	Nirsa	Tolyp
Enaca	Novapesca	Transcity
Estar	Oceanexa	Ultraespec
Expalsa	Oceanfish	Usa Fish
Exporclam	Oceaninvest	
Exporklore	Oceanmundo	

Source: CNA, 2009

b. DESCRIPTION OF WASTE CHARACTERISTICS, HANDLING, AND MANAGEMENT

Shrimp processing consists of the following steps:

- Shrimp cleaning.
- Transfer of cleaned shrimp to a classifier machine that separates shrimp by size. The machine has a shrimp reception hopper in which water and ice are included for keeping shrimp at the appropriate temperature.
- Hand packaging. Shrimp can be packed without or with head. It is also possible to create additional products according to the client's requirements (mainly outside the country). Among the different packages for clients there are different sizes of polyethylene bags or cardboard packing boxes. Further, depending on the client's requirement they can be packaged in boxes only or bags inside the boxes.
- Storage of the packaged product in refrigerated warehouses, from which they are transported to the shipping port.

According to the manual of good practices in the shrimp processing sector developed by the cleaner production centers of Nicaragua and El Salvador,[1] the average water consumption is 60 m^3/ton of shrimp processed.

Two case studies of shrimp packaging companies in Ecuador are presented below.

[1] Manual de Buenas Prácticas Operativas de Producción más Limpia para Procesadoras de Camarón, Elaborado por los Centros de Producción más Limpia de Nicaragua y El Salvador, y por Park Environmental.

OMARSA (Source: Study "Environmental analysis of the product from Ecuadorian aquaculture shrimp from a life cycle perspective")

Inventory of inputs and outputs for the production of 1 MT of processed shrimp, including freezing. Data were obtained from the processing of a complete batch that produced 8,301,020.82 kg of processed shrimp.

- INPUTS
  Materials/fuels
  Water (surface) 21.98 m^3
  Electricity/heat
  Diesel equipment 1.1 Liters
  Electricity Ecuador 943 kWh
- OUTPUTS
  Wastewater
  Suspended solids Not Available
  BOD_5 21.36 kg
  Phosphorus (total) 0.52 kg

  Solid wastes
  Wastes 208 kg

According to the data obtained for a batch, waste after processing of shrimp with heads is 17 percent; that is, for producing a box or bag of 2 kg frozen packed shrimp, 2.4 kg of pool-harvested shrimp are needed.

Water treatment plants make the river water potable for its use in the shrimp production processes and in ice production. Electricity consumption is for all the plants, including the consumption of electricity by the shrimp processing plant itself, the freezer-warehouses, and the ice plants. There is one ice plant for the shrimp processing plant and three ice plants for shipping; the produced ice in the latter is not used in the plant for shrimp processing. A basic engineering calculation indicates that ice production uses less than 10 percent of the plant's electricity consumption. Diesel is sometimes used when electricity generation is required in the plant. The freezing warehouse where packed shrimps are stored is permanently turned on at different seasons of the year, and therefore, the specific average value is used (total energy of complete year 2007/production of complete year 2007).

Wastewater characteristics were taken from registers that the company maintains for the purpose of control and certification audits. The monitored substances are those used for internal controls and audits. Testing is carried out at discharge and in the supplier/receiving body (Guayas River). Data are calculated subtracting the concentration values of the water body from which the water is taken with those of discharge. The values represent an average of all the samples taken by the company during 2007.

Shrimp Packaging Company (Source: Thesis "Design of stabilization lagoons for treatment of wastewaters from the shrimp processing industries")

The study aimed to design a wastewater treatment system for a shrimp packaging plant that would be integrated by two anaerobic lagoons and a facultative one, and that would enable a 94 percent reduction in BOD_5, an 80 percent reduction in dissolved solids, and the total elimination of floating matter.

The selected packaging plant has an average processing capacity of 800,000 lbs/month of shrimp, with an electric energy consumption of 2,400 kWh and water consumption of 140 m^3/day or 4,200 m^3/month.

The average flow of wastewater, considering a consumption of 80 m^3 in 12 hours, is 1.85 L/sec, having the physical-chemical parameters detailed below, according to the laboratory analysis:

Parámetros	Valores	Unidad
Turbiedad	90	UTJ
Color	15	UPt/Co
Olor	Desagradable	
Temperatura ambiente	27	°C
pH a 25 °C	6.8	
Conductvidad específica	660	µ ohmios/cm
Sólidos disueltos	435	mg/l
Sólidos suspendidos	60	mg/l
Sólidos totales	495	mg/l
Sólidos sedimentables	2	ml/l
DBO_5	180	mg/l
DQO	250	mg/l
OD	0	mg/l

4. POTENTIAL FOR METHANE EMISSION REDUCTION

This section presents an estimate of the potential for reducing GHGs from livestock manures and agricultural commodity processing wastes though the use of anaerobic digestion. Anaerobic digestion reduces GHG emissions in two ways. First, it directly reduces methane emissions by capturing and burning biogas that otherwise would escape from the waste management system into the atmosphere. Second, it indirectly reduces carbon dioxide, methane, and nitrous oxide by using biogas to displace fossil fuels that would otherwise be used to provide thermal energy or electricity. Section 4.1 explains the potential methane emission reduction from manure management systems and agricultural commodity processing waste.

The feasibility of modifying existing livestock manure and agricultural commodity processing waste management systems by incorporating anaerobic digestion will depend on the ability to invest the necessary capital and generate adequate revenue to at least offset operating and management costs, as well as provide a reasonable return on the invested capital.

A number of options exist for anaerobically digesting wastes and utilizing the captured methane. For a specific enterprise, waste characteristics will determine which digestion technology options are applicable. Of the technically feasible options, the optimal approach will be determined by financial feasibility, subject to possible physical and regulatory constraints. For example, the optimal approach may not be physically feasible due to the lack of necessary land. Section 4.2 briefly describes the types of anaerobic digestion technology, methane utilization options, costs and benefits, and centralized projects. Appendix D provides more information regarding emissions avoided when wet wastes are sent to landfills, as well as emissions from leakages and waste transportation in co-substrate projects.

4.1 METHANE EMISSION REDUCTION

Anaerobic digestion projects for both manure and agricultural commodity processing wastes may produce more methane than currently is being emitted from the existing waste management system, because anaerobic digesters are designed to optimize methane production. For example, the addition of anaerobic digestion to a manure management operation where manure was applied daily to cropland or pasture would produce significantly more methane than the baseline system. As such, the direct methane emission reduction from a digester corresponds not to the total methane generated, but rather the baseline methane emissions from the waste management system prior to installation of the digester. The indirect emission reduction, as explained in section 4.1.2, is based on the maximum methane production potential of the digester and how the biogas is used.

4.1.1. Direct Emission Reduction from Digestion of Agricultural Commodity Processing Wastes

The methane production potential from agricultural commodity wastes is estimated using Equation 2.2 and the MCF for the baseline waste management system used at the operation, as shown in Equations 4.2 and 4.3:

$$CH_{4(W)} = (TOW_{(W)} - S_{(W)}) \times EF_{(W,S)} \qquad (4.2)$$

where: $CH_{4\,(W)}$ = Annual methane emissions from agricultural commodity processing waste W (kg CH_4 per year)
$TOW_{(W)}$ = Annual mass of waste W COD generated (kg per year)
$S_{(W)}$ = Annual mass of waste W COD removed as settled solids (sludge) (kg per year)
$EF_{(W,\,S)}$ = Emission factor for waste W and existing treatment system and discharge pathway S (kg CH_4 per kg COD)

The methane emission rate is a function of the type of waste and the existing treatment system and discharge pathway, as follows:

$$EF_{(W,\,S)} = B_{o\,(W)} \times MCF_{(S)} \qquad (4.3)$$

where: $B_{o\,(W)}$ = Maximum CH_4 production capacity (kg CH_4 per kg COD)

$MCF_{(S)}$ = Methane conversion factor for the existing treatment system and discharge pathway (decimal)

Table 4.1 shows the estimated GHG emission reduction potential for four agro-industrial subsectors in Ecuador. When the indirect emission reductions are considered, the emission reduction potential ranges from 20,000 $MTCO_2e$ for shrimp processing to nearly 230,000 $MTCO_2e$ for alcohol distilleries. The total potential emission reduction potential across all subsectors is 386,471 $MTCO_2e$ per year. Based on limited data and best professional judgment, the MCF_{AD} value of 0.80 appears to be a reasonable estimate for ambient temperature digesters, for first-order estimates of methane production potential.

Table 4.1 – Methane and Carbon Emission Reductions from Agro-Industrial Waste

	Palm Oil Processing	Sugar Mills	Distilleries	Shrimp Processing	Assumptions
P (MT/year)	373,500	526,543	50,000	66,844	Palm oil: Used 90% of the 2008 crude oil production; average values for W and COD from the plants visited
W (m^3/MT)	0.6	11	13	60	
COD (kg/m^3)	55	3	70	1	
TOW (kg COD/year)	12,325,500	18,534,317	45,500,000	4,010,667	
B_0 (kg CH_4/kgCOD)	0.25	0.25	0.25	0.25	Sugar mills: Used 2005–2006 sugar production; IPCC default values for W and COD; no offsets because use bagasse
MCF	0.8	0.8	0.8	0.8	
EF (kg CH_4/kg COD)	0.2	0.2	0.2	0.2	
CH_4 (MT CH_4/year)	2,465	3,707	9,100	802	
CO_2 (MT CO_2e/year)	51,767	77,844	191,100	16,845	Distilleries: Used yearly average production; W and COD values of Codana
Indirect emission reduction (MT CO_2e/yr)	9,750	0	35,993	3,173	
Total CO_2 (MT CO_2e/yr)	61,517	77,844	227,093	20,017	Shrimp processing: 50% of the plants use lagoons

4.1.2 Indirect GHG Emission Reductions

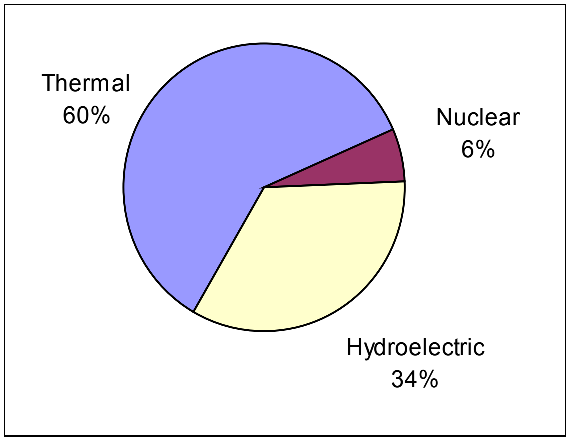
The use of anaerobic digestion systems has the financial advantage of offsetting energy costs at the production facility. Biogas can be used to generate electricity or to supplant the use of thermal fuels. Using biogas energy also reduces carbon emissions from the fossil fuels that are displaced by use of the recovered biogas. The degree of emission reduction depends on how the biogas is used. Table 4.2 shows the potential uses of the biogas in each of the sectors.

Table 4.2 – Potential Biogas Energy Use by Sector

Sector	Electricity Use	Thermal Energy Replacement
Swine farm	Feed mills	Liquefied petroleum gas (LPG) to heat farrow houses and nurseries
Dairy farm	Energy intensive, particularly during milking operations	LPG
Milk processing	Energy intensive – chillers, pumps and engines, compressors	Natural gas/LPG for boiler
Slaughterhouses	Energy intensive – cold chambers, pumps and general equipment	Natural gas for boiler
Sugar mills/distilleries	Energy intensive. Sugar mills don't require electricity from the grid during harvest because they burn bagasse. However, they could sell the energy generated from an anaerobic digestion system.	Natural gas for boiler. Large user of steam in the process, particularly for evaporation and crystallization operations.
Citrus processing	Energy intensive	Natural gas for boiler, rotary and other driers

When biogas is used to generate electricity, the emission reduction depends on the energy sources used by the central power company to power the generators. In Ecuador, the generation sector consists of thermal plants (60 percent), hydroelectric plants (34 percent), and nuclear plants (6 percent), as illustrated in Figure 4.1. The fuels used by the thermal plants are natural gas, diesel, and fuel oil. Many thermal plants in Ecuador are dual fuel, which allows them to use either natural gas or fuel oil. Currently, fuel oil is used most often for both the base and peak loads. Table 4.3 shows the associated carbon emission reduction rate from the replacement of fossil fuels when biogas is used to generate electricity in Ecuador.

Figure 4.1 – Distribution of Electricity Generation in Ecuador



Source: EIA International Energy Annual, 2006

Table 4.3 – Carbon Emissions by Type of Fuel

Fuel Replaced	CO_2 Emission Factors
Generating electricity – depends on fuel mix 100% coal 100% hydro or nuclear	 1.02 kg/kWh from CH_4 0 kg/kWh from CH_4
Natural gas	2.01 kg/m3 CH_4
LPG	2.26 kg/m3 CH_4
Distillate fuel oil	2.65 kg/m3 CH_4

Source: Developed by Hall Associates, Georgetown, Delaware USA

Indirect emissions are estimated by first ascertaining the maximum production potential for methane from the digester and then determining the emissions associated with the energy that was offset from biogas use. For Table 4.1, it was assumed that the collected biogas would be used to generate electricity, replacing fuel oil.

4.1.4 Summary

As illustrated by the equations presented in Section 2.2, the principal factor responsible for determining the magnitude of methane emissions from livestock manure and agricultural commodity processing wastes is the waste management practice employed, which determines the MCF. As shown in Table 10.17 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* and in Tables 2.2 and 2.6 of this report, anaerobic lagoons and landfills have the highest potential for emitting methane from these wastes. Thus, replacing those waste management practices with anaerobic digestion has the greatest potential for reducing methane emissions. While the reduction in methane emissions realized by replacing other waste management practices with anaerobic digestion will not be as significant, the methane captured will be a source of renewable energy with the ability to reduce fossil fuel consumption and the associated GHG emissions from sequestered carbon.

Table 4-4 summarizes the findings of the RA in terms of potential methane emission reductions and carbon offsets in Ecuador. The sector with the highest potential for methane reduction and carbon offsets is the distilleries sector, followed by the sugar mill, palm oil processing, and shrimp processing sectors.

Table 4.4 – Summary of Total Carbon Emission Reductions Identified in Ecuador

Sector	Methane Emission Reductions ($MTCH_4$/yr)	Carbon Emission Reductions ($MTCO_2e$/yr)	Fuel Replacement Offsets ($MTCO_2e$/yr)	Total Carbon Emission Reductions ($MTCO_2e$/yr)
Distilleries	9,100	191,100	35,993	227,093
Sugar mills	3,707	77,844	0	77,844
Palm oil processing	2,465	51,767	9,750	61,517
Shrimp processing	802	16,845	3,173	20,017
TOTAL	16,074	337,556	48,916	386,471

4.2 TECHNOLOGY OPTIONS

4.2.2 Methane Production

There are a variety of anaerobic digestion processes, which can be broadly categorized as either suspended or attached growth processes. The applicability of any specific process is determined primarily by physical characteristics of the waste or mixture of wastes that will be anaerobically digested. Attached growth processes are suitable for wastes with low concentrations of particulate matter. For wastes with higher concentrations of particulate matter, suspended growth processes generally are more suitable. The anaerobic digestion process options that are applicable to the various types of livestock manures and agricultural commodity processing wastes are discussed below.

Livestock Manures: For livestock manures, four anaerobic digestion reactor options exist: 1) plug-flow, 2) mixed, 3) covered lagoon, and 4) attached growth. The appropriate option or options are determined by the concentration of particulate matter, generally measured as total solids (TS) concentration in the collected manure; type of manure; and climate, as shown in Table 4.5. The TS concentration in the collected manure is determined by the method of collection—mechanical (scraping) or hydraulic (flushing)—and the volume of water used for hydraulically collected manures.

Table 4.5 – Overview of Anaerobic Digestion Options for Livestock Manures (After EPA, 2004)

	Plug-flow	Mixed	Covered Lagoon	Attached Growth
Influent TS concentration	11–13 %	3–10	0.5–3	<3
Manure type	Only dairy cattle	Dairy & swine	Dairy & swine	Dairy & swine
Required pretreatment	None	None	Removal of coarse fiber from dairy cattle manure	Removal of coarse fiber from dairy cattle manure
Climate	All	All	Temperate & warm	Temperate & warm

Source: U.S. EPA. 2004.

As indicated in Table 4.5, use of covered lagoons and attached growth reactors for methane production from dairy cattle manure requires removal of coarse fiber—usually by screening—before anaerobic digestion. For the attached growth option, screening of swine manure to remove hair and foreign matter, such as ear tags, is advisable. Covered lagoons and attached growth reactors operate at ambient temperature and thus, are only suitable for temperate and warm climates. In temperate climates, there may be seasonal variation in the rate of methane production.

Agricultural Commodity Processing Wastewater: As discussed above, agricultural commodity processing operations may generate either liquid wastewater, solid waste, or both. No single treatment process, except for the covered anaerobic lagoon, is suitable for all of these wastewaters, due to wide variation in physical and chemical characteristics. Even the physical and chemical characteristics of wastewater from the processing of a single commodity can vary widely, reflecting differences in processing and sanitation practices. For example, some processing plants prevent solid wastes, to the extent possible, from entering the wastewater generated, whereas others do not.

In addition, some plants employ wastewater pretreatment processes such as screening, gravitational settling, or DAF to remove particulate matter, whereas others do not. Although the covered anaerobic lagoon has the advantages of universal applicability and simplicity of operation and maintenance, adequate land area must be available. If the volume of wastewater generated is low, co-digestion with livestock manure or wastewater treatment residuals may be a possibility. Other options for the anaerobic treatment of these wastewaters are briefly described below.

For wastewaters with high concentrations of particulate matter (total suspended solids [TSS]) or extremely high concentrations of dissolved organic matter (BOD or COD), the complete mix, anaerobic contact, or anaerobic sequencing batch reactor (ASBR) processes are alternatives. These are typically operated at mesophilic (30 to 35°C) or thermophilic (50 to 55°C) conditions.

As shown in Table 4.6, the anaerobic contact and ASBR processes operate at significantly shorter hydraulic retention times (HRTs) than the complete mix process. A shorter required HRT translates directly into a smaller required reactor volume and system footprint; however, operation of the anaerobic contact and ASBR processes is progressively more complex.

Table 4.6 – Typical Organic Loading Rates for Anaerobic Suspended Growth Processes at 30°C

Process	Volumetric Organic Loading, kg COD/m^3-day	Hydraulic Retention Time, days
Complete mix	1.0—5.0	15—30
Anaerobic contact	1.0—8.0	0.5—5
Anaerobic sequencing batch reactor	1.2—2.4	0.25—0.50

Source: Metcalf and Eddy, Inc., 2003

For wastewaters with low TSS concentrations or wastewaters with low TSS concentrations after screening or some other form of TSS reduction, such as DAF, one of the anaerobic sludge blanket processes may be applicable. Included are the 1) basic upflow anaerobic sludge blanket (UASB), 2) the anaerobic baffled reactor, and 3) anaerobic migrating blanket reactor (AMBR®) processes. The anaerobic sludge blanket processes allow for high volumetric COD loading rates due to the retention of a high microbial density in the granulated sludge blanket. Wastewaters that contain substances such as proteins and fats that adversely affect sludge granulation, cause foaming, or cause scum formation are problematic. Thus, use of anaerobic sludge blanket processes generally is limited to high-carbohydrate wastewaters.

Attached growth anaerobic processes represent another option for agricultural commodity processing wastewaters with low TSS concentrations. Included are the1) upflow packed-bed attached growth, 2) upflow attached growth anaerobic expanded bed, 3) attached growth anaerobic fluidized bed, and 4) down-flow attached growth reactor processes. All have been used successfully in the anaerobic treatment of a variety of food and other agricultural commodity processing wastewaters but are more operationally complex than the suspended growth and sludge blanket processes.

Agricultural Commodity Processing Solid Wastes. Generally, solid wastes from agricultural commodity processing are most amenable to co-digestion with livestock manure or wastewater treatment residuals in a mixed digester. Although it may be possible to anaerobically digest some of these wastes independently, the addition of nutrients, such as nitrogen or phosphorus, and a buffering compound to provide alkalinity and control pH may be necessary.

4.2.3 Methane Use Options

In addition to methane, carbon dioxide is also a significant product of the anaerobic microbial decomposition of organic matter. Collectively, the mixture of these two gases commonly is known as biogas. Typically, biogas also contains trace amounts of hydrogen sulfide, ammonia, and water vapor. The energy content of biogas depends on the relative volumetric fractions of methane and carbon dioxide. Assuming the lower heating value of methane, 35,755 kJ/m^3, a typical biogas composition of 60 percent methane and 40 percent carbon dioxide has a lower heating value of 21,453 kJ/m^3. Thus, biogas has a low energy density compared to conventional fuels.

Although the principal objective of the anaerobic digestion of livestock manure and agricultural commodity processing wastes is to reduce methane emissions to the atmosphere, biogas has value as a renewable fuel. It can be used in place of a fossil fuel in stationary internal combustion engines or microturbines connected to generator sets or pumps and for water or space heating. Direct use for cooling or refrigeration is also a possibility.

Use of biogas in place of coal, natural gas, LPG, or distillate or heavy fuel oil for water or space heating is the most attractive option due to simplicity and the possibility of utilizing existing boilers or furnaces modified to burn a lower energy density fuel. Conversion of a natural gas- or LPG-fueled boiler or furnace to a biogas furnace generally only requires replacement of the existing metal combustion assembly with a ceramic burner assembly with larger orifices. If there is seasonal variation in demand for water or space heating, biogas compression and storage is an option that should be considered if the cost of suitable storage can be justified.

Using biogas to fuel a modified natural gas internal combustion engine or microturbine to generate electricity is more complex. Livestock manures and most agricultural commodity processing wastes contain sulfur compounds, which are reduced to hydrogen sulfide during anaerobic digestion and partially desorbed. Thus, hydrogen sulfide, in trace amounts, is a common constituent of biogas and can cause serious corrosion problems in biogas-fueled internal combustion engines and microturbines. Hydrogen sulfide combines with the water produced during combustion to form sulfuric acid. Consequently, scrubbing to remove hydrogen sulfide may be necessary when biogas is used to generate electricity.

Using biogas to generate electricity also may require interconnection with the local electricity provider for periods when electricity demand exceeds biogas generation capacity, when generation capacity exceeds demand, or when generator shutdown for maintenance or repairs is necessary. One of the advantages of using biogas to generate electricity connected to the grid is the ability to use biogas as it is produced and to use the local electricity grid to dispose of excess electrical energy when generation capacity exceeds onsite demand. Specifically in the case of Ecuador, the Ministry of Energy is promoting an initiative that aims to supply at least 8 percent of the total national energy consumption through renewable energy systems by 2016. Ecuador has developed several tariff rates to support new electricity generation projects. The use of biogas to generate electricity not only will reduce farm operating costs, but will also provide a steady revenue stream for the farm.

When avoided methane emissions and associated carbon credits are considered, simply flaring biogas produced from the anaerobic digestion of livestock manures and agricultural commodity processing wastes also can be considered an option. However, this can be considered an option only to the degree that replacing the current methane-emitting waste management practice with anaerobic digestion reduces methane emissions. Although systems utilizing biogas from anaerobic digestion as a boiler or furnace fuel or for generating electricity should have the ability to flare excess biogas, flaring should be considered an option only if biogas production greatly exceeds the opportunity for utilization.

4.3 COSTS AND POTENTIAL BENEFITS

The cost of anaerobically digesting livestock manures and agricultural commodity processing wastes and utilizing the methane captured as a fuel depends on the type of digester constructed and the methane utilization option employed. In addition, these costs will vary geographically, reflecting local financing, material, and labor costs. However, it can be assumed that capital cost will increase as the level of technology employed increases. For digestion, the covered anaerobic lagoon generally will require the lowest capital investment, with anaerobic sludge blanket and attached growth processes requiring the highest. As the complexity of the anaerobic digestion process increases, operating and maintenance costs also increase. For example, only basic management and operating skills are required for covered lagoon operation, whereas a more sophisticated level of understanding of process fundamentals is required for anaerobic sludge blanket and attached growth processes.

For captured methane utilization, the required capital investment will be the lowest for flaring and highest for generating electricity. Based on past projects developed in the United States and Latin America, the cost of an engine-generator set will be at least 25 percent of the total project cost, including the anaerobic digester. In addition, while the operating and maintenance costs for flaring are minimal, they can be substantial for generating electricity. For example, using captured biogas to generate electricity requires a continuous engine-generator set maintenance program and may include operation and maintenance of a biogas hydrogen sulfide removal process.

4.3.2 Potential Benefits

Anaerobic digestion of livestock manure and agricultural commodity processing wastes can generate revenue to at least offset and ideally exceed capital and operation and maintenance costs. There are three potential sources of revenue. The first is the carbon credits that can be realized from the reduction of methane emissions by the addition of anaerobic digestion. MCFs, and therefore reduction in methane emissions and the accompanying carbon credits earned, are determined by the existing waste management system and vary from essentially 0 to 100 percent. Thus, carbon credits will be a significant source of revenue for some projects and nearly nothing for others.

The second potential source of revenue is from the use of the biogas captured as a fuel. However, the revenue realized depends on the value of the form of energy replaced and its local cost. Because biogas has no market-determined monetary value, the revenue realized from its use in place of a conventional source of energy is determined by the cost of the conventional source of energy replaced. If low-cost hydropower-generated electricity is available, the revenue derived from using biogas to generate electricity may not justify the required capital investment and operating and maintenance costs. Another factor that must be considered in evaluating the use of biogas to generate electricity is the ability to sell excess electricity to the local electricity provider and the price that would be paid. There may be a substantial difference between the value of electricity used on site and the value of electricity delivered to the local grid. The latter may not be adequate to justify the use of biogas to generate electricity. Ideally, the ability to deliver excess generation to the local grid during periods of low onsite demand and the subsequent ability to reclaim it during periods of high onsite demand under some type of a net metering contract should exist.

The third potential source of revenue is from the carbon credits realized from the reduction in the fossil fuel carbon dioxide emissions when use of biogas reduces fossil fuel use. As with the revenue derived directly from using biogas as a fuel, the carbon credits generated depend on the fossil fuel replaced. In using biogas to generate electricity, the magnitude of the reduction in fossil fuel-related carbon dioxide emissions will depend on the fuel mix used to generate the electricity replaced. Thus, the fuel mix will have to be determined to support the validity of the carbon credits claimed.

4.4 CENTRALIZED PROJECTS

Generally, small livestock production and agricultural commodity processing enterprises are not suitable candidates for anaerobic digestion to reduce methane emissions from their waste streams due to high capital and operating costs. The same is true for enterprises that only generate wastes seasonally. If all of the enterprises are located in a reasonably small geographical area, combining compatible wastes from two or more enterprises for anaerobic digestion located at one of the waste sources or a centralized location is a possible option. By increasing project scale, unit capital cost will be reduced. However, operating costs will increase, and centralized digestion will not always be a viable option if the ability to generate adequate revenue to at least offset the increased operating costs is lacking.

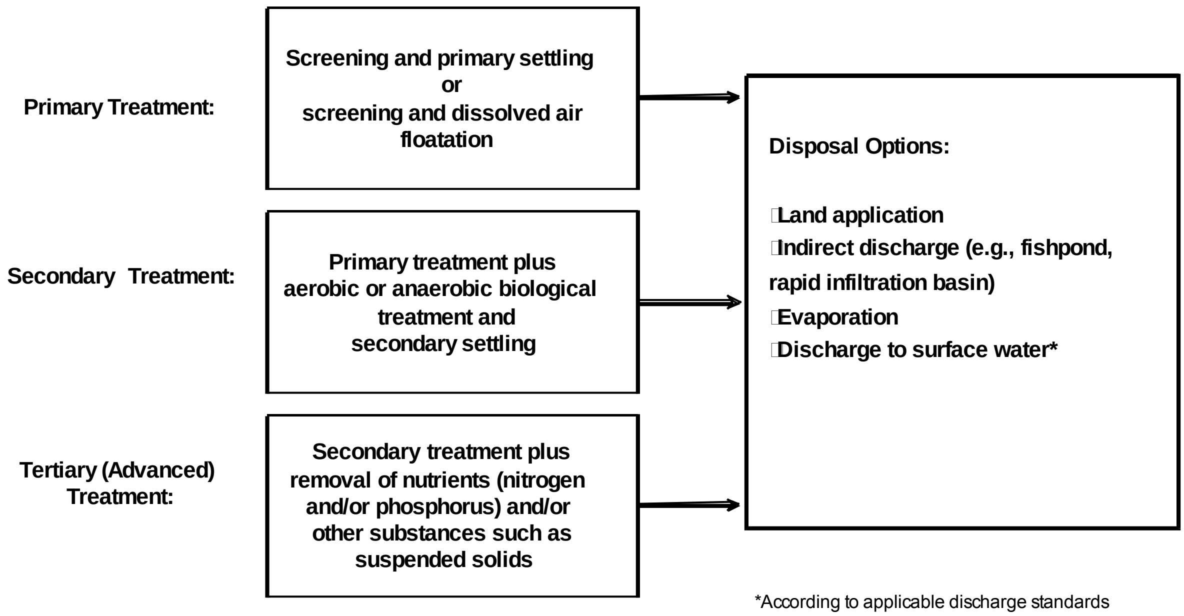
There are two possible models for centralized anaerobic digestion projects. In the first model, digestion occurs at one of the sources of waste, with the waste from the other generators transported to that site. In the model that typically is followed, wastes from one or more agricultural commodity processing operations are co-digested with livestock manure. In the second model, wastes from all sources are transported to a separate site for digestion. The combination of the geographic distribution of waste sources and the options for maximizing revenue from the captured methane should be the basis for determining which model should receive further consideration in the analysis of a specific situation.

For centralized anaerobic digestion projects, the feasibility analysis should begin with the determination of a project location that will minimize transportation requirements for the wastes to be anaerobically digested and for the effluent to be disposed. The optimal digester location could be determined by trial and error, but constructing and applying a simple transportation model would be a more efficient approach. Although obtaining the optimal solution manually is possible, use of linear programming should be considered. With this approach, optimal locations with respect to minimizing transportation costs for a number of scenarios can be obtained and compared. For example, the transportation costs associated with locating the anaerobic digester at the largest waste generator versus a geographically central location can be delineated and compared.

Next, the revenue that will be generated from the selling of carbon credits realized from reducing methane emissions and utilizing the captured methane as a fuel should be estimated. The latter will depend on a number of factors, including the location of the digester and opportunities to use the captured methane in place of conventional sources of energy. Generally, captured methane that can be used to meet onsite electricity or heating demand will have the greatest monetary value and produce the most revenue to at least offset and ideally exceed system capital and operation and maintenance costs. Thus, an energy-use profile for each source of waste in a possible centralized system should be developed to determine the potential for onsite methane use, the revenue that would be realized, and the allocation of this revenue among the waste sources. .

Ideally, the digester location that minimizes transportation costs will be at the waste source with the highest onsite opportunity for methane utilization. Thus, waste transportation costs will be minimized while revenue will be maximized. However, the digester location that minimizes transportation costs may not maximize revenue from methane utilization due to low onsite energy demand. Therefore, alternative digester locations should be evaluated to identify the location that maximizes the difference between revenue generation from methane utilization and transportation costs. Again using a simple transportation-type model to determine the optimal digester location is recommended. If the optimal location is not at one of the waste sources, additional analysis incorporating site acquisition costs will be necessary.

APPENDIX A: TYPICAL WASTEWATER TREATMENT UNIT PROCESS SEQUENCE



*According to applicable discharge standards

This appendix provides further detail on the subsectors included in Chapter 3. It also presents information on other subsectors with low methane emissions or insufficient data to calculate methane emission reductions: swine, dairy farms, banana farms, and slaughterhouses.

SWINE

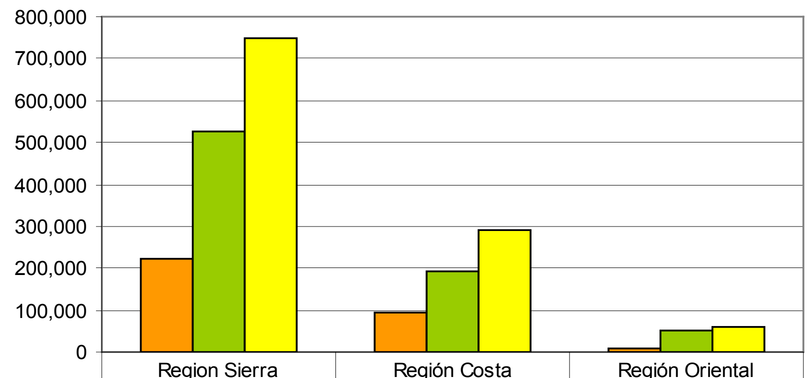
Description of size, operations scale, and geographical location

Although the swine sector in Ecuador is not very large, it involves 500,000 people with an average annual consumption of about 8.5 kg/person/year over the past 10 years.

According to the numbers published in ESPAC 2008, the total number of swine is 1,097,251,[2] with 324,864 head younger than two months old and 772,387 head older than two months.

Figure B.1 shows the distribution of swine in the three regions of the country. The Sierra region (Región Sierra) contains 68 percent of the swine population with 747,335 heads, followed by the Coast region (Región Costa) with 26 percent and 289,810 heads, and the East region (Región Oriental) with 5.5 percent and nearly 60,000 heads.

Figure B.1. Distribution of Swine by Region and Age, 2008



	Region Sierra	Región Costa	Región Oriental
Menores 2 meses	222,366	95,750	6,748
Mayores 2 meses	524,969	194,060	53,358
Total	747,335	289,810	60,106

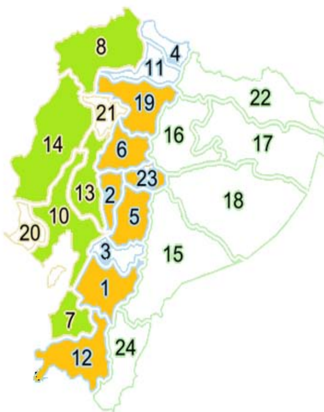
Source: ESPAC, 2008
("Menores 2 meses" translates as "Younger than 2 months;" "Mayores 2 meses" translates as "Older than 2 months")

Regarding the distribution of swine by province, as observed in Figure B.2 below, the largest number of swine are located in Pichincha (15 percent), Cotopaxi (13 percent), Loja (10 percent), and Chimborazo (8 percent) in the Sierra region and in the provinces of Manabí (9

[2] This number would be showing a decrease of swine in the last years. The registries from III CNA show a national total of 1,527,114 head, while ESPAC 2004 shows this value as 1,281,774 head.

percent) and Guayas (6 percent) in the Coast region. The highest sale rates correspond to Pichincha (26 percent) and Manabí (11 percent).

Figure B. 2. Distribution of Swine by Province, 2008



Provincia			
1	Azuay	13	Los Ríos
2	Bolivar	14	Manabí
3	Cañar	15	Morona Santiago
4	Carchi	16	Napo
5	Chimborazo	17	Orellana
6	Cotopaxi	18	Pastaza
7	El Oro	19	Pichincha
8	Esmeraldas	20	Santa Elena
9	Galápagos	21	Santo Domingo de los Tsáchilas
10	Guayas	22	Sucumbíos
11	Imbabura	23	Tungurahua
12	Loja	24	Zamora Chinchipe

Provincia	Existencia (cab.)		Ventas (cab.)	
Pinchincha	176,211	15%	68,725	26%
Cotopaxi	146,733	13%	23,448	9%
Loja	120,005	10%	15,345	6%
Manabí	100,023	9%	29,368	11%
Chimborazo	87,942	8%	16,536	6%
Guayas	72,326	6%	13,593	5%
Azuay	67,292	6%	12,535	5%
Bolivar	54,194	5%	6,848	3%
Centro-Sur Oriente	43,623	4%	10,900	4%
Tungurahua	42,084	4%	8,748	3%
Los Ríos	40,228	3%	5,030	2%
Esmeraldas	39,813	3%	7,014	3%
El Oro	37,418	3%	11,462	4%
Otras	69,357	6%	16,448	6%

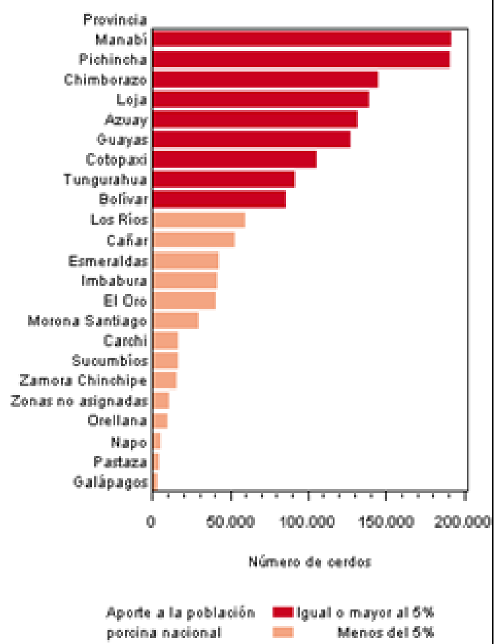
Source: Prepared by the authors

According to III CNA (2000), the total swine population was 1,527,114 head divided among 440,475 farms (an average of 3.5 pigs/farm) in the following way: 72.9 percent of the farms with one or more pigs were located in the Sierra region, 21.8 percent in the Coast region, and 4.8 percent in the East region. These data demonstrate that in the Coast region, the farms have a higher average number of pigs than in the Sierra region: 4.7 pigs/farm and 3.5 pigs/farm, respectively.

The farms distribution by province can be seen in Figure B.3. The provinces that house more than 5 percent of swine population in the country were: Manabí (12.4 percent), Pichincha (12.4 percent), Chimborazo (9.4 percent), Loja (9 percent), Azuay (8.5 percent), Guayas (8.2 percent), Cotopaxi (6.8 percent), Tungurahua (5.9 percent), and Bolívar (5.5 percent).

Figure B.3. Distribution of Swine by Province and Farms, 2000

	Fincas		Cabezas	
	Número	%	Número	%
Provincia				
Azuay	56.031	12,7	130.108	8,5
Bolívar	26.472	6,0	84.094	5,5
Cañar	19.314	4,4	52.262	3,4
Carchi	6.332	1,4	15.823	1,0
Cotopaxi	39.151	8,9	104.033	6,8
Chimborazo	54.481	12,4	142.788	9,4
El Oro	7.268	1,6	39.958	2,6
Esmeraldas	7.107	1,6	41.276	2,7
Guayas	28.468	6,5	125.873	8,2
Imbabura	15.313	3,5	40.228	2,6
Loja	35.480	8,1	137.902	9,0
Los Ríos	16.747	3,8	58.251	3,8
Manabí	36.640	8,3	189.412	12,4
Morona Santiago	8.321	1,9	28.489	1,9
Napo	978	0,2	3.954	0,3
Pastaza	1.066	0,2	3.155	0,2
Pichincha	28.646	6,5	189.102	12,4
Tungurahua	39.817	9,0	89.878	5,9
Zamora Chinchipe	3.923	0,9	14.791	1,0
Galápagos	240	0,1	2.464	0,2
Sucumbíos	4.305	1,0	15.153	1,0
Orellana	2.437	0,6	8.746	0,6
Zonas no asignadas	1.939	0,4	9.372	0,6
Total	440.475	100,0	1.527.114	100,0

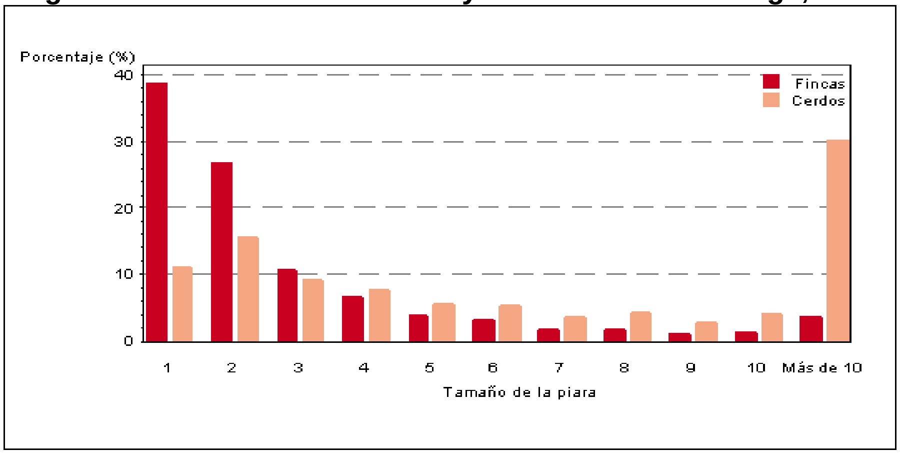


Source: INEC, 2002

(“Número de credos” translates as “Number of swine;” “Aporte a la población porcina nacional” translates as “Contribution to national population; “Igual o mayor al 5%” translates as “Greater than or equal to 5%;” “Menos del 5%” translates as “Less than 5%”)

The farms included in III CNA's data had a small number of pigs per farm. More than three-fourths of the farms had between one and three pigs, which amounted to 35.8 percent of the country's swine farms. Farms with more than 10 pigs per farm made up only 3.7 percent of the swine farms concentrating 30.2 percent of the swine population. Figure B.4 summarizes distribution of swine by farm size.

Figure B.4. Swine Distribution by Farms and Percentage, 2000



Source: INEC, 2002
("Tamaño de la piara" translates as "Herd size;" "Más de 10" translates as "More than 10," "Fincas" translates as "Farms," "Cerdos" translates as "Swine")

According to reports from SESA, only 15 percent of swine were managed in a corporate setting. The majority were managed in family-type settings with a very low possibility of incorporating modern technology and genetic improvements. The type of swine in Ecuador is formed by a series of crossbred animals of diverse breeds, which have adapted to the ecological conditions present at the swine facilities.

Recent estimates indicate that Ecuador produces about 135,000 metric tons of pork meat annually, from which nearly 39 percent come from the 200 industrial-type farms with the highest productivity. About 300 farms provide another 36 percent of the production. These farms are already becoming industrialized, but they still have lower productivity levels. The remaining production comes from small farms and backyard breeding. Ecuador also buys significant amounts of pork meat from Chile.

Description of the Characteristics of Wastes, Handling, and Management

It was not possible to obtain specific information regarding the effluent composition of swine farms or the handling practices that are generally followed in the country.

However, there was information that one of the major producers of the country, Pronaca, has implemented anaerobic digestion systems at approximately 90 percent of its farms. This could indicate that the methane emission reduction potential may be high.

Additional information about Ponaca is provided in Figure B.5, below.

Figure B.5: Case Study: Pronaca: Animal Waste Management in Three Swine Breeding Facilities

PRONACA

Case study: "Pronaca: animal waste management in three swine breeding facilities"

In August 2002, Pronaca started a voluntary improvement process for managing liquid wastes from its swine facilities. The improvements promoted in its swine breeding/fattening facilities reduce methane emissions at the facilities.

Previously, Pronaca placed animal wastes in traditional anaerobic lagoons. Manure generated on the farms was washed with water, and the water-manure mixture was taken to oxidation lagoons. In these lagoons, the mixture was evaporated, in part, but it was also pumped to sites where it was naturally decomposed. However, it is well known that anaerobic lagoons are an important source of methane, nitrous oxide, and ammonia. Further, this traditional management method produced unpleasant odors and required significant amounts of water for cleaning the farms.

In addition to the implementation of its anaerobic lagoon system, Pronaca implemented a deep bedding system, which consists of the application of rice husks on the farms' floors where pigs are located. Husk acts as a sponge that absorbs manure and urine from animals, producing a mixture with a low moisture content that is used as fertilizer The process for producing, managing, and applying this fertilizer results in a reduction of methane emissions and nitrous oxide compared to the anaerobic lagoon option. In addition, the deep bedding system reduces the amount of wash water, eliminates the use of oxidation lagoons and their unpleasant odors, reduces the amount of disturbed land, and improves the well-being and comfort of the pigs.

Location

The projects are located at the following swine breeding farms: Valentina/San Javier, Afortunados, and Tropicales/Plata.

Reduction of GHG emissions

- Valentina/San Javier: 9,100 $MTCO_2e$ per year
- Afortunados: 6,000 $MTCO_2e$ per year
- Tropicales/Plata: 5,800 $MTCO_2e$ per year

Status

The systems are in operation at the three facilities. However, Pronaca's goal is to implement this process at all its facilities. This will depend to a large extent on the income generated by the CDM component.

Report on Corporate Responsibility 2008

Biodigesters: In the area of Santo Domingo, six biodigesters that process organic wastes from nine swine farms were built. Each system has an area between 3,000 and 9,000 m^2, which is determined by the farm's demand. The process is complemented by an irrigation system for pastures.

Eight wastewater processing plants have been built for different operations of the company. These systems facilitate compliance with the environmental standards and parameters contained in the Ecuadorian legislation. There are water treatment plants in the poultry and swine slaughterhouses, incubators, and added value food processing plants. The size and capacity of each facility varies according to the process needs.

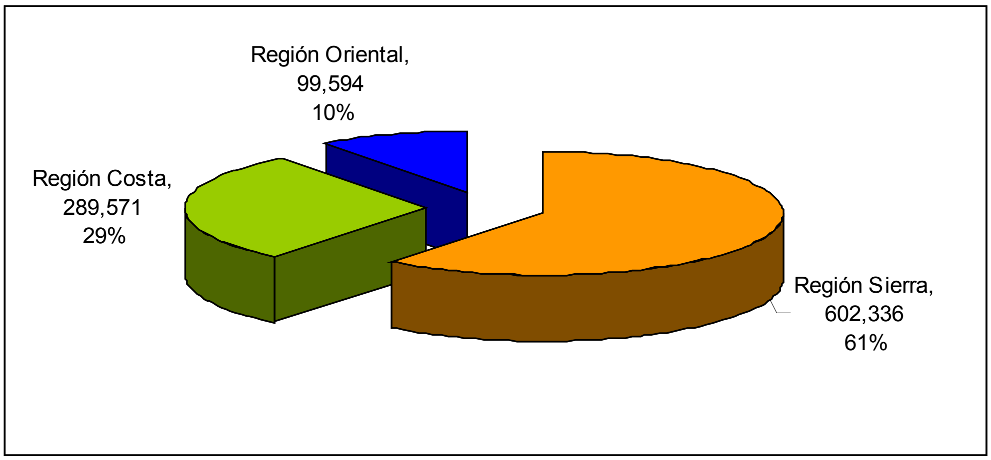
DAIRY FARMS

Description of the Size, Operations Scale, and Geographical Location

Milk production in Ecuador is concentrated in the Sierra region, and to a lesser extent in the Coastal region. According to ESPAC 2008, the country has 971,342 dairy cows that produced 5,325,653 L of milk.

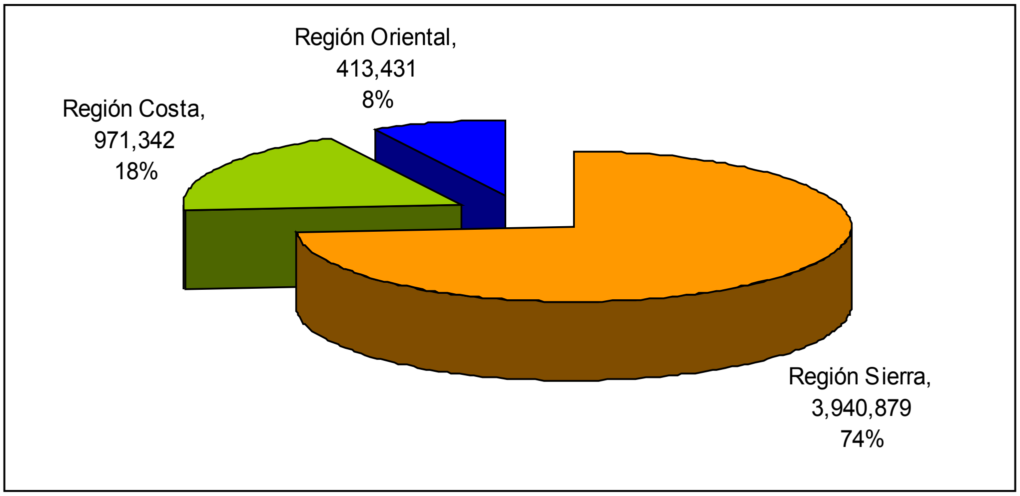
Figure B.6 presents the distribution of dairy cows by region and Figure B.7 shows the distribution of milk produced by region.

Figure B.6. Number of Dairy Cows by Region, 2008



Source: ESPAC, 2008
("Región Sierra" translates as "Sierra Region;" "Región Costa" translates as "Coast Region;" and "Región Oriental" translates as "East Region.")

Figure B.7. Liters of Produced Milk by Region, 2008



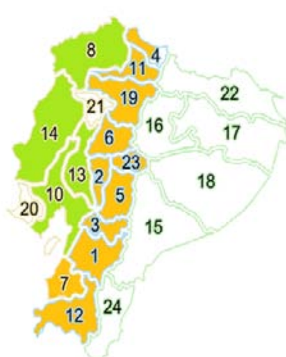
Source: ESPAC, 2008

("Región Sierra" translates as "Sierra Region;" "Región Costa" translates as "Coast Region;" and "Región Oriental" translates as "East Region.")

The Sierra region has 602,336 dairy cows, representing 61 percent of the total dairy population. The Sierra region also produces 3,940,879 L of milk, which represents 74 percent of the total production. The Coast region has approximately 290,000 dairy cows, representing 29 percent of the total population, and produces 971,000 L of milk, representing 18 percent of the total production.

The distribution of dairy cattle and milk production by province can be seen in Figure B.8. Although most of the milk production is concentrated in the Sierra region, with the Province of Pichincha leading (14 percent of cows and 19 percent of the milk production), the Province of Manabí in the Coast region is highlighted, with 16 percent of the dairy cows and 10 percent of the milk production.

Figure B. 8. Distribution of Dairy Cows by Province, 2008



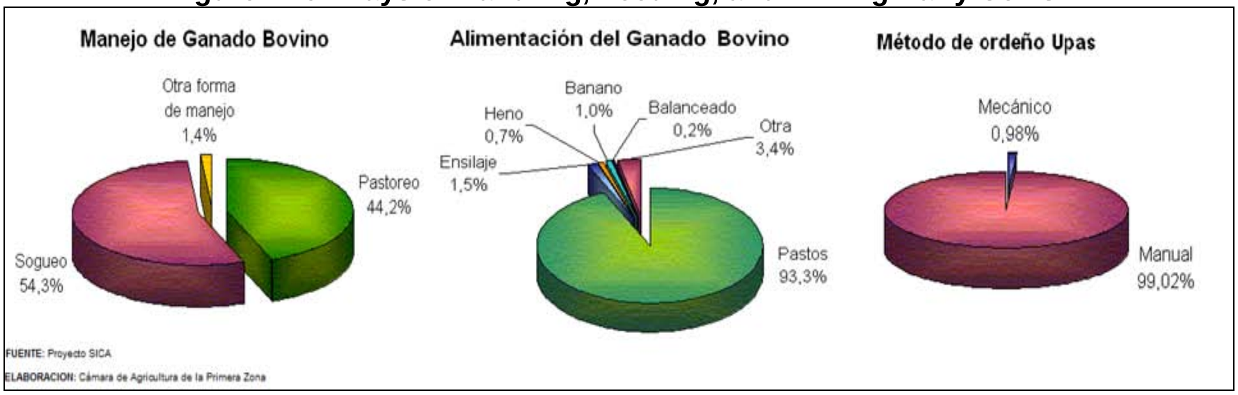
Provincia			
1	Azuay	13	Los Ríos
2	Bolívar	14	Manabí
3	Cañar	15	Morona Santiago
4	Carchi	16	Napo
5	Chimborazo	17	Orellana
6	Cotopaxi	18	Pastaza
7	El Oro	19	Pichincha
8	Esmeraldas	20	Santa Elena
9	Galápagos	21	Santo Domingo de los Tsáchilas
10	Guayas	22	Sucumbíos
11	Imbabura	23	Tungurahua
12	Loja	24	Zamora Chinchipe

Provincia	Vacas ordeñadas		Producción leche	
	N°	%	Lts	%
Manabí	178,668	16%	573,069	10%
Pichincha	149,542	14%	1,086,336	19%
Azuay	90,685	8%	463,833	8%
Cotopaxi	69,630	6%	471,597	8%
Centro-Suroriente	67,013	6%	264,202	5%
Chimborazo	60,002	5%	369,675	6%
Guayas	50,550	5%	174,451	3%
Tungurahua	49,565	5%	453,857	8%
Loja	45,181	4%	165,730	3%
Carchi	39,904	4%	375,579	6%
Bolívar	39,645	4%	163,434	3%
Cañar	37,427	3%	239,292	4%
Otras	113,291	10%	522,598	9%

Source: Prepared by the authors

Regarding cattle management and feeding, as well as the milking methods of the milk producers' UPAs, the information from III CNA indicates a high predominance of grazing (44 percent) and grass feeding (93 percent) and a practice of hand milking of 99 percent of the dairy UPAs. This is presented in Figure B.9.

Figure B. 9. Ways of Handling, Feeding, and Milking Dairy Cows



Source: III CNA

("Manejo de Ganado Bovino" translates as "Handling of Dairy Cows;" "Alimentación del Ganado Bovino" translates as "Feeding of Dairy Cows" and "Método de ordeño Upas" translates as "Method of Milking")

Table B.1 shows the relationship between UPA size, milked cows, and milking method.

Table B. 1 Relationship Between UPA Size, Milked Cows, and Milking Method

METODOS DE ORDEÑO Y DESTINO DE LA LECHE			TOTAL NACIONAL	TAMAÑOS DE UPA										
				Menos de 1 Ha	De 1 hasta menos de 2 Has.	De 2 hasta menos de 3 Has.	De 3 hasta menos de 5 Has.	De 5 hasta menos de 10 Has.	De 10 hasta menos de 20 Has.	De 20 hasta menos de 50 Has.	De 50 hasta menos de 100 Has.	De 100 hasta menos de 200 Has.	De 200 Has y más
NUMERO DE VACAS ORDEÑADAS		UPAs	237,315	39,014	30,247	22,801	27,795	32,338	27,330	31,556	16,132	6,808	3,295
		Cabezas	808,856	52,232	45,558	39,396	54,720	80,210	87,353	151,665	119,962	87,581	90,179
METODO DE ORDEÑO	Manual	UPAs	234,984	38,771	30,093	22,699	27,626	32,126	27,078	31,122	15,828	6,541	3,101
			99%	99%	99%	100%	99%	99%	99%	99%	98%	96%	94%
	Mecánico	UPAs	2,332	243	154	102	169	212	252	435	303	268	194
			1%	1%	1%	0%	1%	1%	1%	1%	2%	4%	6%

III CENSO NACIONAL AGROPECUARIO-DATOS NACIONALES_______________________________________ECUADOR
INEC-MAG-SICA

Hand milking appears as the common practice and only in UPAs with more than 100 Ha (that amounted to about 178,000 head at the time of the III CNA). The use of mechanical milking was employed at 4 to 6 percent of UPAs. If this situation remains, the possibilities of waste treatment would be significantly restricted due to the lack of available structures.

There is only one farm in the country that is known to keep its cattle enclosed in buildings for milking and feeding. This farm has about 1,000 cows.

Description of Characteristics of Wastes, Handling and Management

There is no data on the wastewater characteristics at dairy farms in Ecuador. Most wastes are diverted via slopes, where they circulate until reaching a creek.

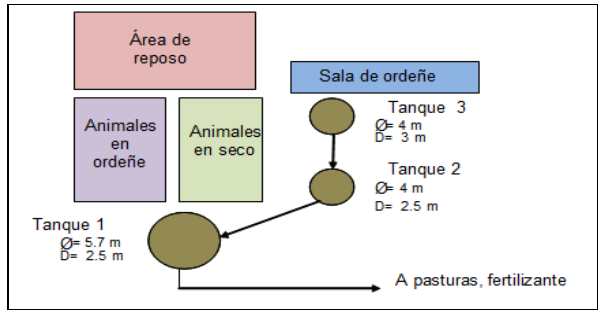
The characteristics of the Reysahiwal dairy farm are summarized in Figure B.10 below.

Figure B.10. Characteristics of Reysahiwal Dairy Farm

Reysahiwal AGR, Wong Group (Source: Visit to the establishment)	
750 milking animals (average weight 450 kg) 250 dry cows (average weight 550 kg) 285 lactation days, 2,200 L/animal/year Grazing, mechanical milking 40 m^3/day wash water There are four in-ground anaerobic lagoons with irregular shape and slope in which the retention time is minimal.	 

Reysahiwal AGR, Wong Group (Source: Visit to the establishment)	
	

Hacienda Chivería (Source: Visit to the establishment)	
450 milking animals, 100 dry cows. Only farm in the country with enclosed system. Chiveria has the best animal breeds and insufficient space for grazing. Milk production 750,000 L/year (approx. 750 MT/year) 80–100 m^3 of wastewaters generated per day COD, BOD are not measured Effluents are pumped at 27°C into three tanks, from which they are taken to pastures and used as fertilizers. The solid residues resulting from the tanks drying are used as fertilizers.	 

Reysahiwal AGR, Wong Group (Source: Visit to the establishment)	
	

BANANA FARMS

Description of Size, Operations Scale, and Geographical Location

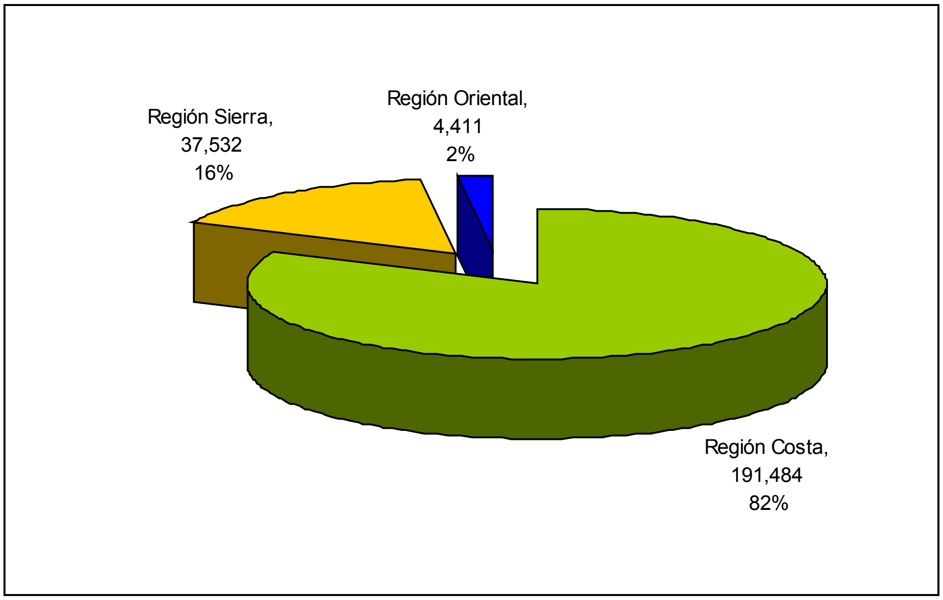
The Ecuadorian banana industry is the leading private sector exportation product after crude oil. In 2006, 242,689,934 boxes of bananas were exported, representing an income of about US$ 1.1 billion in foreign currency. These numbers represent 32 percent of the bananas traded worldwide, 3.84 percent of the total GDP, 50 percent of the agriculture GDP, and 20 percent of the private exports of the country.

In 2006, investments in banana production achieved an estimated US$ 920 million for cultivated plantations, infrastructure, and banana packaging companies. This amount increases to US$ 1.7 billion if the investments in collateral industries are considered[3].

As seen in the following figures (Figures B.11 and B.12), and according to ESPAC 2008, the Coast region has about 82 percent of the banana plantations in approximately 191,000 Ha, with production and sales volumes of nearly 6,000,000 MT. The Sierra region has 16 percent of the plantations and production and sales values of less than 300,000 MT.

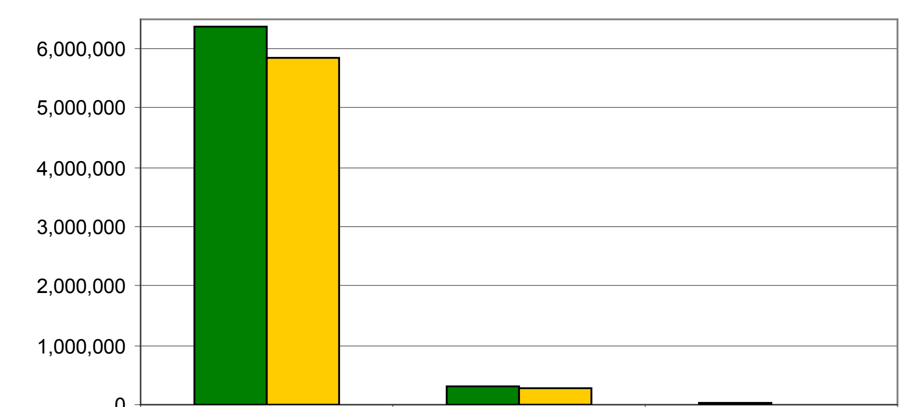
[3] Analysis of the Ecuadorian banana sector during year 2006, AEBE, http://www.aebe.com.ec/Desktop.aspx?Id=93.

Figure B. 11. Banana Plantation Surface (Ha), 2008



Source: ESPAC, 2008
("Región Sierra" translates as "Sierra Region;" "Región Costa" translates as "Coast Region;" and "Región Oriental" translates as "East Region.")

Figure B. 12. Banana Production and Sales (MT), 2008

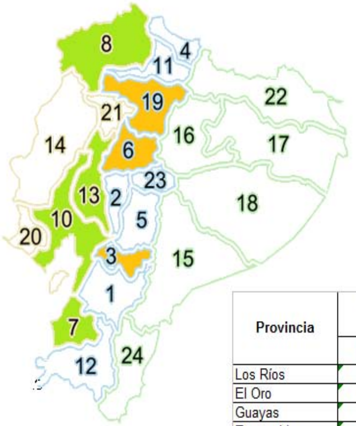


	Región Costa	Región Sierra	Región Oriental
Producción	6,380,615	299,039	21,491
Ventas	5,839,252	274,952	10,817

Source: ESPAC, 2008
("Región Sierra" translates as "Sierra Region;" "Región Costa" translates as "Coast Region;" and "Región Oriental" translates as "East Region;" "Producción" translates as "Production;" and "Ventas" translates as "Sales")

Figure B.13 shows that the main banana producers are Los Ríos, El Oro, Guayas, and Esmeralda in the Coast region and Cañar, Cotopaxi, and Pichincha in the Sierra region, The planted Ha and MT produced and sold are also indicated.

Figure B.13. Main Banana Producer Provinces, 2008[4]



Provincia			
1	Azuay	13	Los Ríos
2	Bolivar	14	Manabí
3	Cañar	15	Morona Santiago
4	Carchi	16	Napo
5	Chimborazo	17	Orellana
6	Cotopaxi	18	Pastaza
7	El Oro	19	Pichincha
8	Esmeraldas	20	Santa Elena
9	Galápagos	21	Santo Domingo de los Tsáchilas
10	Guayas	22	Sucumbíos
11	Imbabura	23	Tungurahua
12	Loja	24	Zamora Chinchipe

Provincia	Sup. plantada		Producción		Ventas	
	Has	%	Tm	%	Tm	%
Los Ríos	57,994	25%	2,421,373	36%	2,252,980	37%
El Oro	61,801	26%	2,104,645	31%	1,873,171	31%
Guayas	44,456	19%	1,766,793	26%	1,664,303	27%
Esmeraldas	14,422	6%	49,660	1%	33,955	1%
Cañar	6,782	3%	123,884	2%	120,310	2%
Cotopaxi	3,768	2%	102,908	2%	102,613	2%
Pichincha	4,110	2%	40,871	1%	39,335	1%
Otras	40,090	17%	91,010	1%	38,353	1%

Source: ESPAC, 2008

2003 data[5] indicate that more than 85 percent of the total producers are small, with plantations of up to 40 Ha, and that they comprise about 40 percent of the sown surface. The average size of a small plantation is 11 Ha. Large producers represent 3.4 percent of the total producers with more than 100 Ha and comprise about 30 percent of the sown surface, demonstrating a high concentration of banana production in a few large producers. This is illustrated in Table B-2 and Figure B.14.

Table B.2. Banana Production Structure in Ecuador, 2003

Size	Number of Producers	% Participation	Surface Area (Ha)	% Participation	Average Plantation Size (Ha)
Small (0 to 40 Ha)	5,295	85.54%	63,333	41.40%	11.96
Medium (41 to 100 Ha)	686	11.08%	43,555	28.47%	63.49

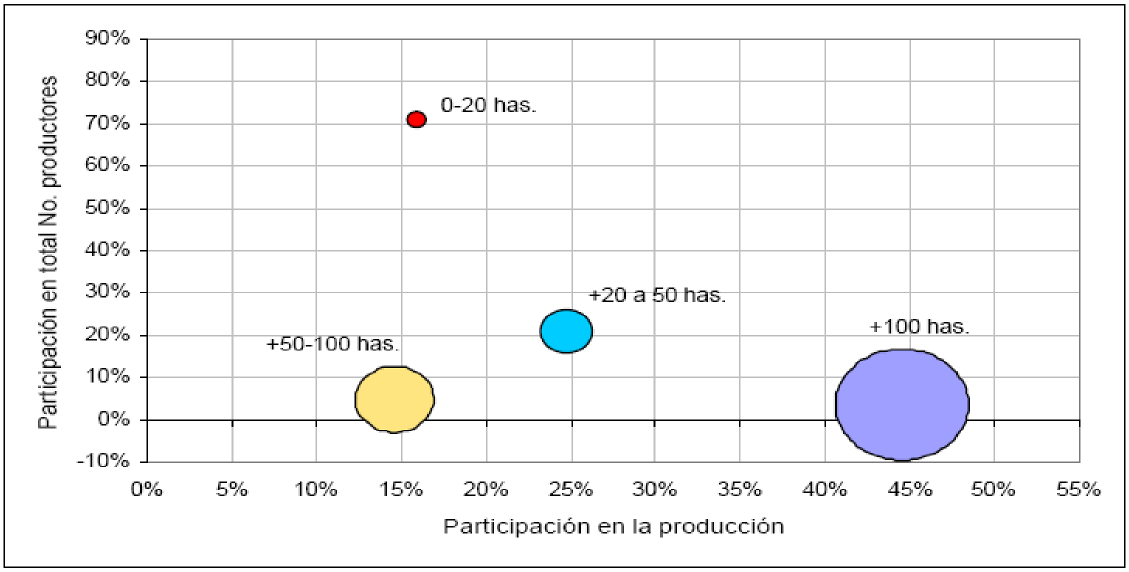
4 It i s under stood t hat t he P rovince of S anto D omingo de l os T sáchilas appe ars w ith no r egisters because the surveyed UPAs located in the same province were also counted in the nearby provinces.

5 Banana in Ecuador, structure and price formation, Direction of Economical Research of the Central Bank of Ecuador, January 2004. On data from the III Agriculture and Livestock National Census and own surveys, focused in the main producer provinces.

Size	Number of Producers	% Participation	Surface Area (Ha)	% Participation	Average Plantation Size (Ha)
Large (100+ Ha)	209	3.38%	46,077	30.12%	220.47
Total	6,190	100%	152,967	100%	21,71

Source: Regional Coast Subsecretariat

Figure B.14. Distribution of Banana Production in Ecuador, 2003



Fuente: III Censo Nacional Agropecuario y Subsecretaría Regional Litoral

Regarding the geographical distribution of producers, Table B.3 and Figure B.15 show that 46 percent of the producers are located in El Oro. Of this percentage, more than 90 percent encompass between 1 and 40 Ha. About 31 percent of the producers are located in the province of Guayas, of which 85 percent are small. 14 percent of the banana producers are located in Los Rios. Los Rios also contains the highest percentage of medium and large producers. As additional data, in Esmeraldas, nearly 80 percent of the producers are small (less than 20 Ha), and the remaining 20 percent have between 21 and 120 Ha.

Table B.3. Distribution of Producers by Province and Plantation Size, 2003

Province	Total	0–40 Ha	41–100 Ha	More than 100 Ha
El Oro	46%	92%	7%	1%
Guayas	31%	85%	11%	4%
Los Ríos	14%	62%	27%	10%

Source: Regional Coast Subsecretariat

Figure B.15. Distribution of Banana Production by Province, 2003

Source: BCE Report, 2004

The productive structure of the banana sector is heterogeneous and varies according to the geographical zone, with an high number of small producers located in El Oro and Guayas. However, when including in the analysis the contribution of each group to total banana production, small producers are less significant. Although small producers (having units between 1 and 20 Ha) represent 70 percent of the total number of producers, they generate about 16 percent of the bananas. In contrast, large producers represent 3 percent of the total producers but represent 45 percent of the banana production in the country, and medium-size producers represent 26 percent of the producers but contribute 40 percent of the total production. In Los Ríos the concentration is more accentuated: 10 percent of producers are large-sized and represent almost 65 percent of the production.

Description of the Characteristics of Wastes, Handling, and Management

The wastes generated by the banana industry can be classified by stage, as shown in Table B.4.

Table B.4. Wastes Generated by the Banana Industry

Stage	Type of Waste	Use/Treatment
Farm/plantation	Shoots, leaves, flowers	Disposal in plantation
Packaging plants	Rachis	Disposal in plantation, compost, paper production
	Rejection	Processing for food industry or human and animal consumption; disposal in ditches, plantation, or landfill; compost
	Wastewater	Waste separation systems in traps, sedimentation lagoon, irrigation
Food industry	Skin	Preparation of compost, animal food
	Wastewater	Facultative lagoons

It was not possible to obtain information regarding the effluent composition from banana wastewaters and waste handling and management practices in Ecuador.

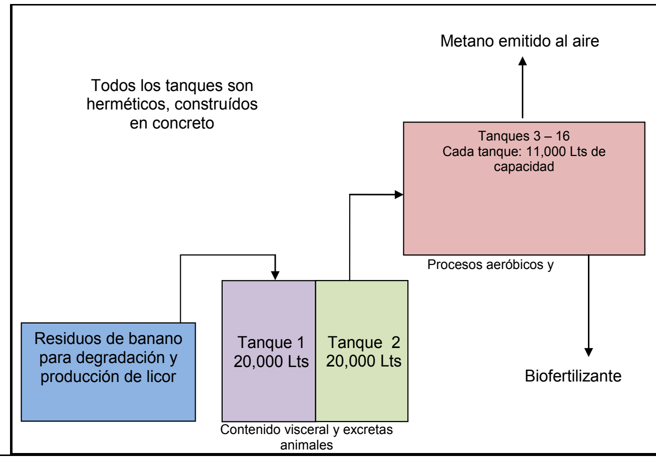
There was access to one establishment, Hacienda El Rosario, in which biogas is generated during biofertilizer production from a technology developed locally, taking advantage of cattle manure and the addition of bacteria and chemicals. Specific data for this establishment are presented in Figure B-16 below.

Figure B.16. Farm Characteristics of El Rosario

Farm El Rosario (Source: Visit to the establishment)

10,000 000 L/week of biofertilizer

Biogas is generated during biofertilizer production using a local technology. Several tanks are used to collect organic wastes from the cattle. With the addition of bacteria, chemicals, and aerobic and anaerobic processes, the biofertilizer is produced. In general, this practice is isolated in such way that the banana sector would not have the potential for generating methane emissions. From 6,000 banana producers, only between 15 and 20 use some type of fertilizer preparation process, according to the comments by the technician in charge of the visited plant.

Farm El Rosario (Source: Visit to the establishment)	
	

SLAUGHTERHOUSES

Description of Size, Operations Scale, and Geographical Location

According to the information from MAGAyP presented in Table B.5, Ecuador has more than 200 slaughterhouses: 45 percent in the Sierra region, 38 percent in the Coast region, and 17 percent in the East and Galápagos regions. Most are the property of and managed by municipalities; 81 percent of slaughterhouses are located in urban areas, 7 percent in semi-urban areas, and 12 percent are rural.

With the exception of private slaughterhouses, which acquire the provision animals and trade butchered meat, the municipalities render services, including the pre- and post-mortem sanitary inspection. Due to the nature of the trade and destination of pork meat, there is still clandestine slaughtering occurring in an estimated 10 percent of the total slaughterhouses, which should be included to the value presented above.

Table B.5. Slaughtering and Meat Production by Province, 2005

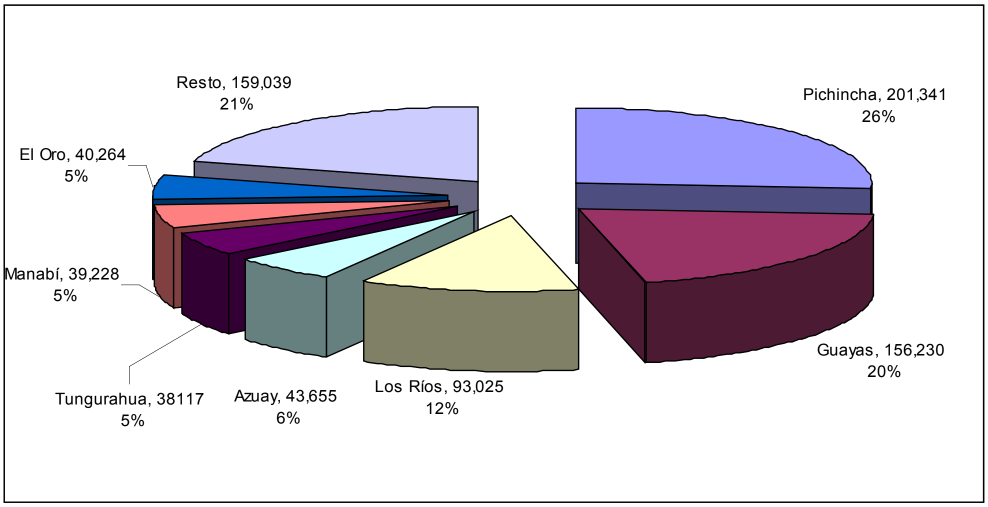
Province	Cattle 2005				Swine			
	# Slaughtered Heads		Carcass Meat Produced (MT)		# Slaughtered Heads		Carcass Meat Produced (MT)	
Carchi	5,327	1%	986	1%	17,207	4%	1,118	4%
Imbabura	22,514	3%	4,188	3%	14,155	3%	920	3%
Pichincha	201,341	26%	38,375	27%	80,861	17%	5,660	18%
Cotopaxi	21,792	3%	4,053	3%	5,387	1%	377	1%
Tungurahua	38,117	5%	7,052	5%	1,192	0%	83	0%
Bolivar	1,560	0%	292	0%	1,993	0%	130	0%
Chimborazo	30,647	4%	5,639	4%	40,732	9%	2,648	9%
Cañar	8,178	1%	1,505	1%	7,166	2%	502	2%
Azuay	43,655	6%	8,120	6%	15,209	3%	1,065	3%
Loja	24,246	3%	4,461	3%	50,348	11%	3,273	11%
Esmeraldas	20,785	3%	3,866	3%	11,528	2%	692	2%
Manabí	39,228	5%	7,296	5%	35,911	8%	2,155	7%
Los Ríos	93,025	12%	17,117	12%	18,952	4%	1,137	4%
Guayas	156,230	20%	28,902	20%	129,485	28%	8,417	27%
El Oro	40,264	5%	7,409	5%	24,260	5%	1,456	5%
Napo	2,022	0%	384	0%	235	0%	14	0%
Pastaza	4,190	1%	796	1%	3,253	1%	195	1%
M.Santiago	6,862	1%	1,304	1%	2,777	1%	167	1%
Zamora CH	3,667	0%	697	0%	1,448	0%	100	0%
Sucumbios	2,490	0%	473	0%	6,154	1%	369	1%
Orellana	2,143	0%	407	0%	1,278	0%	77	0%
Galápagos	2,616	0%	481	0%	1,238	0%	74	0%
Total	770,899	100%	143,803	100%	470,769	100%	30,629	100%

Source: MAGAyP, 2005

As observed in the table, during 2005, 770,899 cattle were slaughtered with a meat production of 143,803 MT, and 470,769 swine were slaughtered with a meat production of 30,629 MT.

Regarding cattle, Figure B.17 shows that the Province of Pichincha contains 26 percent of the operations, with 201,341 slaughtered head, followed by Guayas, with 156,230 head representing 20 percent of the operations. In third place is the Province of Los Ríos, with 12 percent, then Azuay, Tungurahua, Manabí, and El Oro, each representing between 5 and 6 percent of the operations.

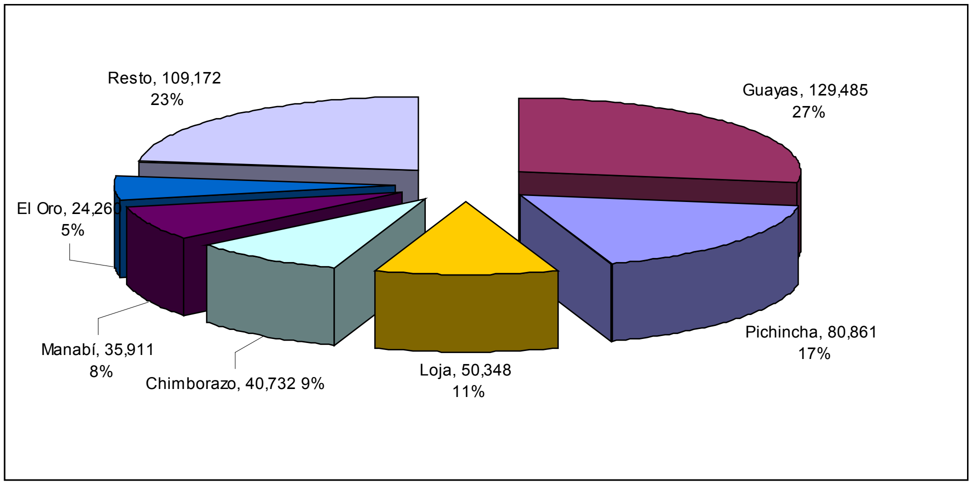
Figure B.17. Slaughtered Cattle by Province, 2005



Source: MAGAyP, 2005

As shown in Figure B.18,.the majority of swine operations are in Guayas, with 27 percent, followed by Pichincha, with 17 percent; Loja, 11 percent; Chimborazo, 9 percent; Manabí, 8 percent; and El Oro, 5 percent.

Figure B.18. Slaughtered Swine by Province, 2005



Source: MAGAyP, 2005

Agropesa is the most modern industrial slaughterhouse in the country. It produces blood meal, meat meal, sebum, pet toys, and organic fertilizer. In 2007, Agropesa produced 15,333,405 kg of beef and pork meat.

Description of Characteristics of Wastes, Handling and Management

It was not possible to obtain information regarding the composition of effluent and management practices at slaughterhouses in Ecuador. Figure B.19 presents site data for one slaughterhouse.

Figure B.19. Site Data for Camal Municipal of Guayquil

Camal Municipal of Guayaquil (Source: Visit to the establishment)

Slaughtered cows: 8,000–9,000/month, 470/day

Slaughtered pigs: 5,000–6.000/month, 350/day

Wastes: 20–25 tons/day

Wastewaters: 400 m^3/day

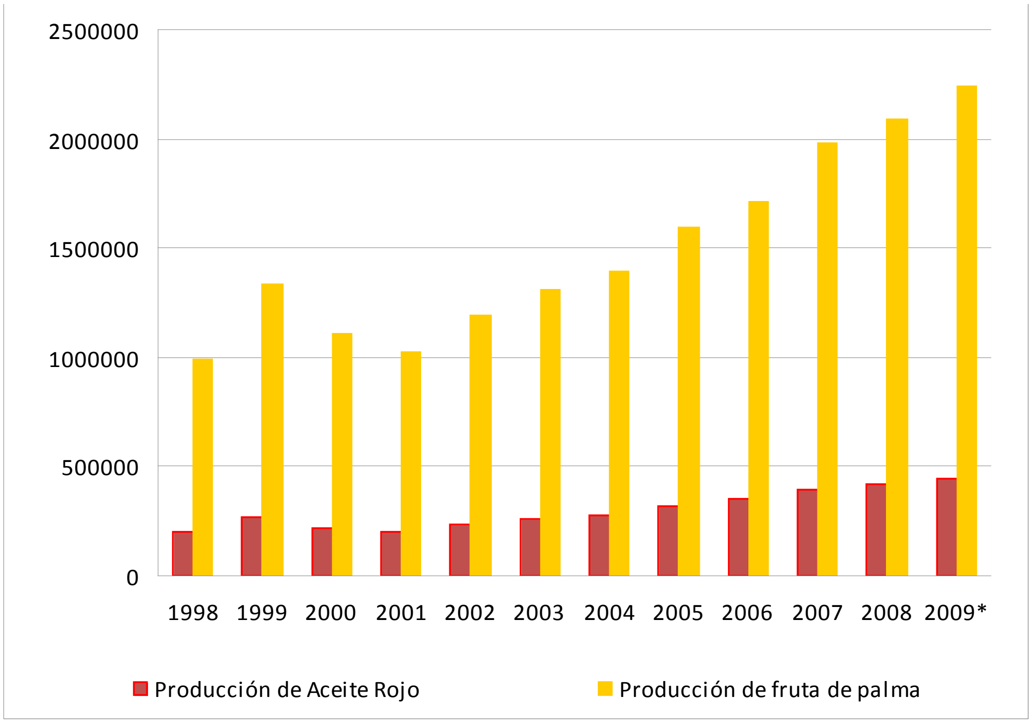
The ruminal content, blood, manure, bones, and head are withdrawn daily and taken to the farm NON S.A., where they are processed for use as fertilizer.

According to information published by the company, there is a wastewater treatment plant in Agropesa that uses a physical-biological process and allows the discharge of effluent to the environment, complying with all Ecuadorian and international standards and regulations.

PALM OIL PROCESSING PLANTS

Additional information on the palm oil processing sector is presented in Figure B.20 below.

Figure B.20 Production of Palm Fruit and Palm Oil in Ecuador



("Producción de Aciete Rojo" translates as "Production of Palm Oil" and "Producción de fruta de palma" translates as "Production of palm fruit")

APPENDIX C: GLOSSARY

Acetogenesis—The formation of acetate (CH_3CO_2H) from carbon dioxide and hydrogen. Many methanogens grow and form methane from acetate.

Acidogenesis—The formation of primarily short-chain volatile acids, such as acetic, proprionic, butyric, valeric, and caproic, from simple soluble compounds produced during hydrolysis.

Activated Sludge Process—A biological wastewater treatment process in which a mixture of wastewater and activated sludge (biosolids) is agitated and aerated. The activated sludge is subsequently separated from the treated wastewater by sedimentation and wasted or returned to the process as needed.

Advanced Waste Treatment—Any physical, chemical, or biological treatment process used to accomplish a degree of treatment greater than achieved by secondary treatment.

Aerated Pond or Lagoon—A wastewater treatment pond or lagoon in which mechanical or diffused aeration is used to supplement the oxygen supplied by diffusion from the atmosphere.

Aerobic—Requiring the presence of free elemental oxygen.

Aerobic Bacteria—Bacteria that require free elemental oxygen to sustain life.

Aerobic Digestion—The degradation of organic matter, including manure, by the action of microorganisms in the presence of free elemental oxygen.

Aerobic Waste Treatment—Waste treatment brought about through the action of microorganisms in the presence of air or elemental oxygen. The activated sludge process is an example of an aerobic waste treatment process.

Anaerobic—The absence of air or free elemental oxygen.

Anaerobic Bacteria—Bacteria that grow only in the absence of free elemental oxygen.

Anaerobic Contact Process—Any anaerobic process in which biomass is separated from the effluent and returned to a complete mix or contact reactor so that the solids retention time (SRT) is longer than the hydraulic retention time (HRT).

Anaerobic Digester—A tank or other vessel for the decomposition of organic matter under anaerobic conditions.

Anaerobic Digestion—The degradation of organic matter, including manure, by the action of microorganisms in the absence of free elemental oxygen.

Anaerobic Pond or Lagoon—An open treatment or stabilization structure that involves retention under anaerobic conditions.

Anaerobic Sequencing Batch Reactor (ASBR) Process—A batch anaerobic digestion process that consists of the repetition of the following four steps: 1) feed, 2) mix, 3) settle, and 4) decant/effluent withdrawal.

Anaerobic Waste Treatment—Waste stabilization brought about through the action of microorganisms in the absence of air or elemental oxygen. Usually refers to waste treatment by methane fermentation. Anaerobic digestion is an anaerobic waste treatment process.

Attached Film Digester—An anaerobic digester in which the microorganisms responsible for waste stabilization and biogas production are attached to inert media.

Bagasse—The fibrous residue remaining after sugarcane or sorghum stalks are crushed to extract their juice. Bagasse is currently used as a renewable resource in the manufacture of pulp and paper products and building materials.

Bacteria—A group of universally distributed and normally unicellular microorganisms lacking chlorophyll.

Biochemical Oxygen Demand (BOD)—A measure of the quantity of oxygen utilized in the biochemical oxidation of organic matter in a specified time and at a specified temperature. It is not related to the oxygen requirements in chemical combustion, being determined entirely by the availability of the material as biological food and by the amount of oxygen utilized by the microorganisms during oxidation.

Biogas—A mixture of methane and carbon dioxide produced by the bacterial decomposition of organic wastes and used as a fuel.

Biological Treatment Processes—There are two general types of biological waste treatment processes: suspended and attached growth. Suspended growth processes generally involve mixing to enhance contact between the microbial population and the wastewater constituents. Suspended growth processes can be either aerobic or anaerobic. The activated sludge process is an example of suspended growth wastewater treatment process.

Attached growth processes are characterized by the development of a microbial population attached to a natural or artificial media when exposed to wastewater constituents. The trickling filter is an example of an attached growth wastewater treatment process. Attached growth processes also can be either aerobic or anaerobic.

Cesspool—A lined or partially lined underground pit into which wastewater is discharged and from which the liquid seeps into the surrounding soil. Sometimes called a leaching cesspool.

Chemical Oxygen Demand (COD)—A quantitative measure of the amount of oxygen required for the chemical oxidation of carbonaceous (organic) material in wastewater using inorganic dichromate or permanganate salts as oxidants in a two-hour test.

Chemical Unit Processes—Processes that remove dissolved and suspended wastewater constituents by chemically induced coagulation and precipitation or oxidation. An example is the addition of alum or lime to remove phosphorus by precipitation in tertiary treatment.

Clarifier—Any large circular or rectangular sedimentation tank used to remove settleable solids from water or wastewater. Special types of clarifiers, called upflow clarifiers, use floatation rather than sedimentation to remove solids.

Complete Mix Digester—A controlled temperature, constant volume, mechanically or hydraulically mixed vessel operated anaerobically for the stabilization of organic wastes, including manures, with biogas generated and captured as a product of waste stabilization.

Compost—The production of the microbial oxidation of organic wastes, including livestock, manures at an elevated temperature.

Composting—The process of stabilizing organic wastes, including livestock manures, by microbial oxidation, with the conservation of microbial heat production to elevate process temperature.

Covered Lagoon Digester—A pond or lagoon operated anaerobically for the stabilization of organic wastes, including manures, and fitted with an impermeable cover to capture the biogas generated as the product of waste stabilization.

Digester—A tank or other vessel for the aerobic or anaerobic decomposition of organic matter present in biosolids or other concentrated forms of organic matter, including livestock manures.

Dissolved Air Floatation (DAF)—A separation process in which air bubbles emerging from a supersaturated solution become attached to suspended solids in the liquid undergoing treatment and float them up to the surface for removal by skimming.

Effluent—The discharge from a waste treatment or stabilization unit process.

Evaporation Pond—A pond or lagoon used for the disposal of wastewater by evaporation.

Facultative—Having the ability to live under different conditions (e.g., with or without free oxygen).

Facultative Bacteria—Bacteria that can carry out metabolic activities, including reproduction, in the presence or absence of free elemental oxygen.

Facultative Pond or Lagoon—A natural or constructed pond or lagoon with an aerobic upper section and an anaerobic bottom section so that both aerobic and anaerobic processes occur simultaneously.

Five-Day BOD—That part of oxygen demand usually associated with biochemical oxidation of carbonaceous material within five days at 20°C.

Greenhouse Gas (GHG)—A gas present in the atmosphere, which is transparent to incoming solar radiation but absorbs the infrared radiation reflected form the earth's surface. The principal GHGs are carbon dioxide, methane, and chlorofluorocarbons.

Human Sewage (Domestic Wastewater) —Human sewage is wastewater that contains human urine and feces. It also usually contains wastewater from bathing and washing of dishes, kitchen utensils, clothing, etc. and may include food preparation wastes. It may be discharged directly, treated on site prior to discharge, or transported by a collection system for direct discharge or treatment in a centralized wastewater treatment plant followed by discharge. Human sewage also is known as domestic wastewater.

Hydraulic Retention Time (HRT)—The volume of a reactor divided by the volumetric flow rate.

Hydrolysis—The reduction of insoluble organic and complex soluble organic compounds to simple soluble organic compounds.

Influent—Wastewater flowing into a unit waste treatment or stabilization process.

Lagoon—Any large holding or detention structure, usually with earthen dikes, used to contain wastewater while sedimentation and biological oxidation or reduction occurs.

Liquid Manure—Manure having a total solids (dry matter) content not exceeding 5 percent.

Manure—The mixture of the fecal and urinary excretions of livestock, which may or may not contain bedding material.

Mesophilic Digestion—Digestion by biological action at 27°C to 38°C.

Methane—A colorless, odorless, flammable gaseous hydrocarbon that is produced from the anaerobic, microbial decomposition of organic matter.

Methanogenesis—The formation of methane from CO_2-type, methyl, and acetoclastic-type substrates.

Municipal Wastewater—Wastewater that can contain domestic, commercial, and industrial wastewaters and is treated in a municipal (publicly owned) treatment plant.

Organic Matter—Chemical substances of animal or vegetable origin, or more accurately, containing carbon and hydrogen.

Oxidation Pond—A relatively shallow body of wastewater contained in an earthen basin of controlled shape, in which biological oxidation of organic matter is effected by the natural or artificially accelerated transfer of oxygen.

Physical Unit Processes—Processes that remove particulate matter in wastewater. Screening and gravity separation to remove particulate matter are examples of physical unit processes. These processes are used for primary treatment and following secondary and tertiary treatment. A typical example of the use of physical unit processes in a wastewater treatment system is primary settling followed by the activated sludge treatment process, which is then followed by secondary settling before final effluent discharge.

Plug-Flow—Flow in which fluid particles are discharged from a tank or pipe in the same order in which they entered it. The particles retain their discrete identities and remain in the tank for a time equal to the theoretical retention time.

Plug-Flow Digester—A controlled temperature, constant volume, unmixed vessel operated anaerobically for the stabilization of organic wastes, including manures, with the capture of biogas generated as a product of waste stabilization.

Primary Treatment*—1) The first major treatment in a wastewater treatment facility, usually sedimentation but not biological oxidation. 2) The removal of a substantial amount of suspended matter but little or no colloidal and dissolved matter. 3) Wastewater treatment processes usually consisting of clarification with or without chemical treatment to accomplish solid-liquid separation.

Psychrophilic Digestion—Digestion by biological action below 27°C.

Raw Wastewater—Wastewater before it receives any treatment.

Secondary Treatment*—1) Generally, a level of treatment that produces removal efficiencies for BOD and suspended solids of at least 85 percent. 2) Sometimes used interchangeably with the concept of biological wastewater treatment, particularly the activated sludge process. Commonly applied to treatment that consists chiefly of clarification followed by a biological process, with separate sludge collection and handling.

Solids Retention Time (SRT)—The average time in which solids, including the population of active microbial biomass, remain in a reactor.

Septic Tank—An underground vessel for treating wastewater by a combination of settling and anaerobic digestion. Effluent usually is disposed of by leaching. Settled solids are removed periodically for further treatment or disposal.

Settling Pond—An earthen basin in which wastewater containing settleable solids is retained to remove a part of suspended matter by gravity. Also called a settling or sedimentation basin.

Stabilization—Reduction in the concentration of putrescible material by either an aerobic or anaerobic process. Both aerobic and anaerobic digestion are examples of waste stabilization processes.

Suspended Solids—1) Insoluble solids that either float on the surface of, or are in suspension in water, wastewater, or other liquids. 2) Solid organic or inorganic particles (colloidal, dispersed, coagulated, flocculated) physically held in suspension by agitation or flow. 3) The quantity of material removed from wastewater in a laboratory test, as prescribed in “Standard methods for the Examination of Water and Wastewater” and referred to as nonfilterable residue.

Tertiary Treatment*—The treatment of wastewater beyond the secondary or biological stage. Term normally implies the removal of nutrients, such as nitrogen and phosphorus, and a high percentage of suspended solids. Term now being replaced by preferred term, “advanced waste treatment.”

Thermophilic Digestion—Digestion carried on at a temperature approaching or within the thermophilic range, generally between 43°C and 60°C.

Total Solids—The sum of dissolved and suspended solid constituents in water or wastewater.

Treatment—The use of physical, chemical, or biological processes to remove one or more undesirable constituents from a waste.

Upflow Anaerobic Sludge Blanket (UASB) Reactor—An upflow anaerobic reactor in which influent flows upward through a blanket of flocculated sludge that has become granulated.

Volatile Solids (VS)—Materials, generally organic, that can be driven off by heating, usually to 550°C; nonvolatile inorganic solids (ash) remain.

Vinasse—The residual liquid from the distillation of ethanol. Sugarcane or sugar beet is processed to produce crystalline sugar, pulp, and molasses. The latter are further processed by fermentation to ethanol, ascorbic acid, or other products. After the removal of the desired product (e.g., alcohol, ascorbic acid), the remaining material is called vinasse.

Wastewater—The spent or used water of a community or industry, which contains dissolved and suspended matter.

Wastewater Treatment System*—A sequence of unit processes designed to produce a final effluent that satisfies standards for discharge to surface or ground waters. Typically will include the combination of primary and secondary treatment processes.

*Appendix A illustrates the typical wastewater treatment process.

APPENDIX D: BIBLIOGRAPHY

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