Methane to Markets

Results of the Ecuador Resource Assessment Report

Roberto A. Urquizo
Director of Environment
Provincial Government of Guayas, Ecuador

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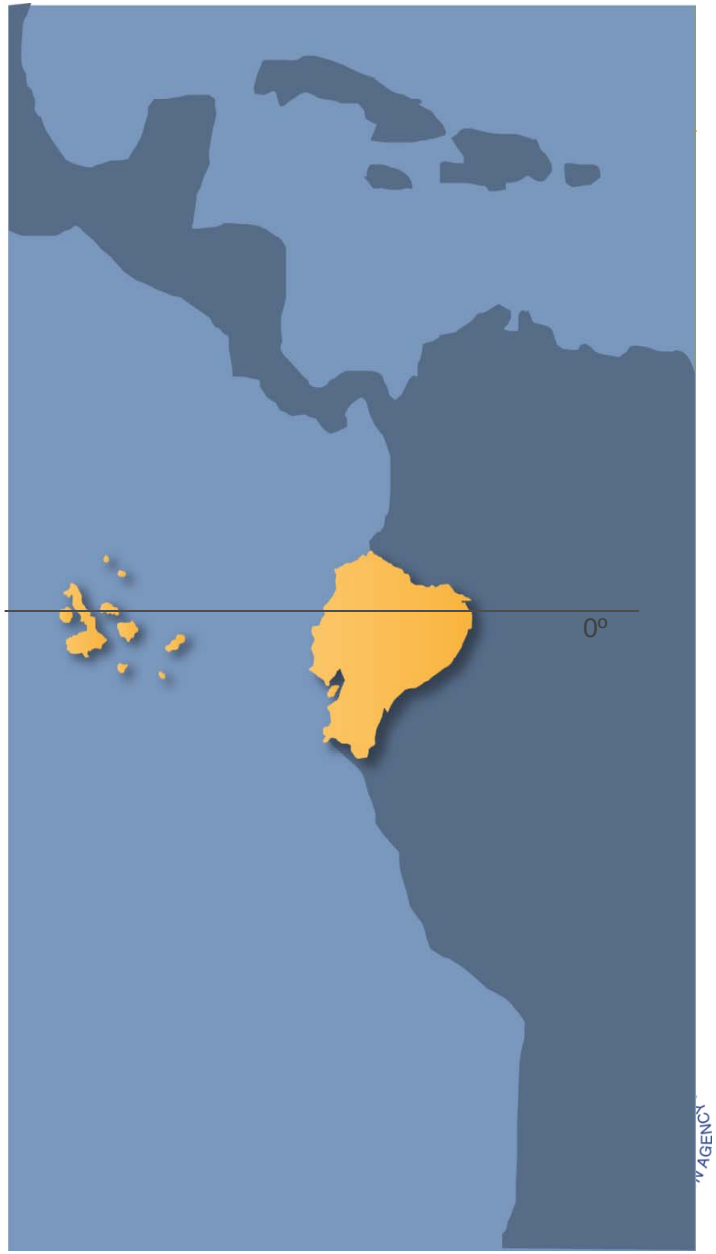
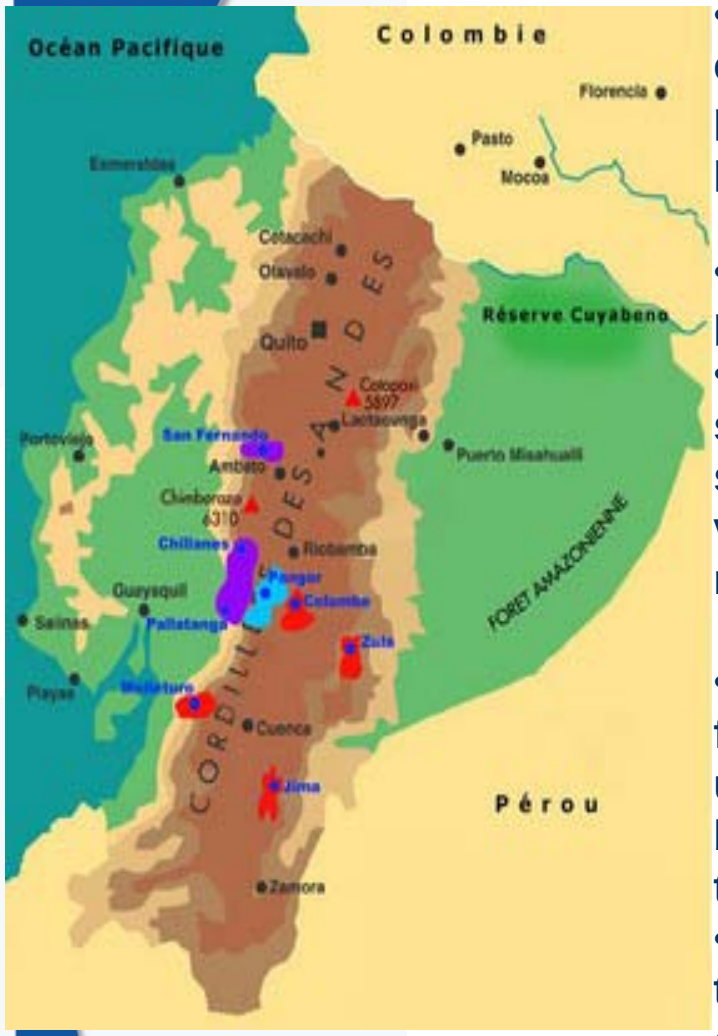


REGIONS OF ECUADOR

Ecuador has four 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.
- Forrest region, Eastern region or the Amazon Region
- The Galápagos Islands are 600 miles to the west of the equatorial coast

DESCRIPTION OF THE REGIONS



- The Coastal region has generally low elevations, not exceeding 800 meters above sea level, and have six provinces. Guayas Province is one of the six provinces of this region.

- 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, 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. Natural Reserved and National Parks are among this area.

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•All regions of Ecuador have agriculture and livestock production. The Coastal and Sierra regions have the greatest production.

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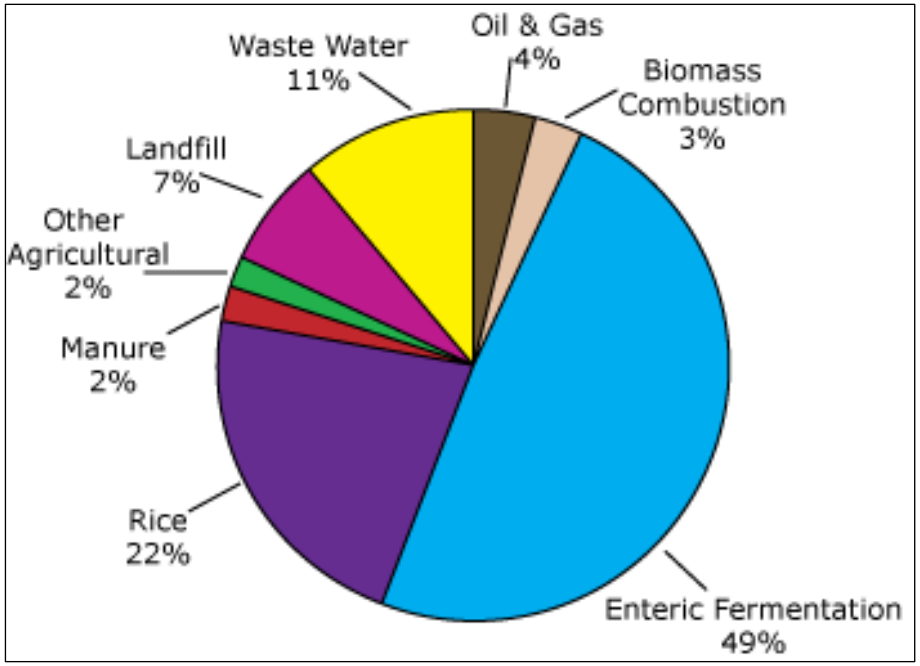
METHANE EMISSIONS IN ECUADOR

- **Ecuador developed a methane emissions country profile in 2005.**
- **The profile estimated the total GHG emissions from the farming sector using EPA's *Global Anthropogenic Emissions of Non-CO_2 Greenhouse Gases* report.**

Ecuador's Estimated Anthropogenic Methane Emissions by Source (2005), Total = 15.46 $MMTCO_2e$



Source: 2006 U.S. EPA Report: Global Anthropogenic Non-CO_2 Greenhouse Gases

METHODOLOGY USED IN THE RESOURSE ASSESSMENT REPORT

1. Source Data
2. Approach Used
3. Estimation factors used for methane emissions in the livestock and agro-industrial sectors in Ecuador
   - 3.1 Manure-Related Emissions
   - 3.2 Agricultural Commodity Processing Waste- Related Emissions
     - 3.2.1 Wastewater Methane Emissions
     - 3.2.2 Solid Wastes Methane Emissions

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SOURCE DATA

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

•**Interviews** with local experts from ministries, 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.

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APPROACH USED

- **Step 1:** Construct general profiles of the individual subsectors (or commodity groups):
  - 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 determined 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:** The team focused on identifying those commodity groups in each sector with the greatest potential to emit methane from waste management activities.

APPROACH USED

- **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.

- When information about waste management practices is incomplete or not readily accessible, the team identified and directly contacted producer associations and local consultants and visited individual operations to obtain this information.

APPROACH USED

•**Step 5**: The team assessed the magnitudes of current methane emissions to identify those commodity groups that should receive further analysis.

- 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
- 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.

The process of estimating current methane emissions was focused on those sectors that could most effectively utilize available resources.

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ESTIMATION FACTORS USED FOR METHANE EMISSIONS IN THE LIVESTOCK AND AGRO-INDUSTRIAL SECTORS IN ECUADOR

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.

2. Agricultural Commodity Processing Waste-Related Emissions

- Agricultural commodity processing can generate two sources of methane emissions: wastewater and solid organic wastes.

- Solid organic waste can include unprocessed raw material or material discarded after processing due to spoilage, poor quality, or other reasons.

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3. Wastewater Methane Emissions:

•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) were used.

•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

4. Solid Wastes Methane Emissions:

•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.

•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.

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SPECIFIC CRITERIA FOR DETERMININGMETHANE EMISSIONS REDUCTION POTENTIAL AND FEASABILITY OF ANAEROBIC DIGESTION SYSTEMS

- **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.

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TOP INDUSTRIES THAT MEET ALL OF THE CRITERIA

- Palm oil processing
- Sugar mills
- Alcohol distilleries
- 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.
- Other livestock sectors, such as beef cattle and poultry, were not considered because the methane emissions generated from those sectors are low.

SECTOR CHARACTERIZATION

1. Introduction
2. Subsectors with potential for methane emission reduction

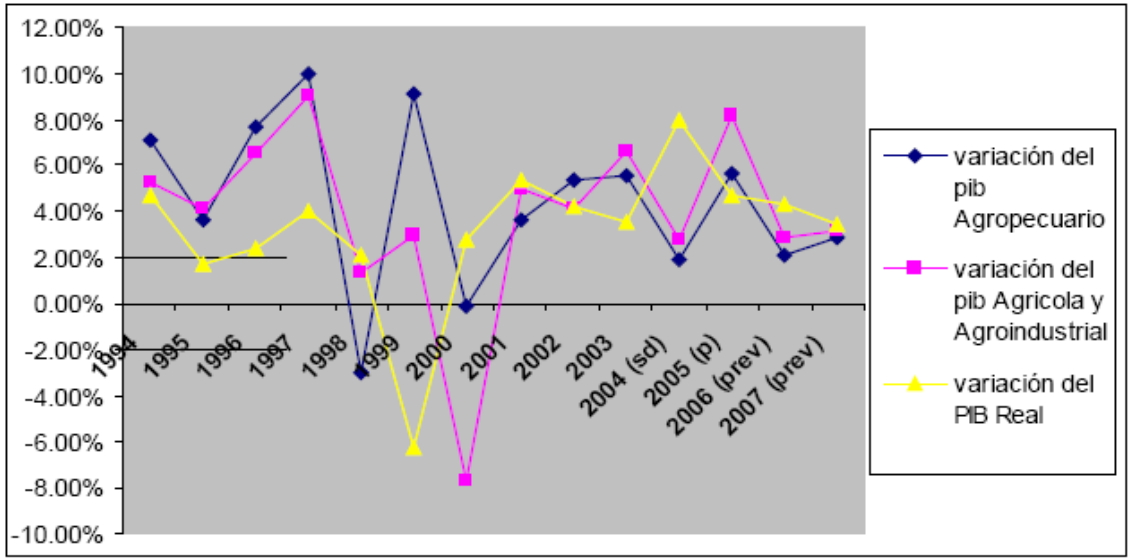
   2.1 Palm Oil Processing Plants
   2.2 Sugar mills
   2.3 Alcohol Distilleries
   2.4 Shrimp Processing




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).

Agricultural and Agro-Industrial GDP Variation (1995 – 2007)



Fuente: Cuentas Nacionales del Banco Central del Ecuador.

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- Livestock production in Ecuador has progressively increased over time.

- 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 million birds roughly, 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.

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SUBSECTORS WITH POTENTIAL FOR METHANE EMISSION REDUCTION

•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 sectors are largely located in the Coast and Sierra regions

Due to limited available data, detailed discussions were not developed for the swine, dairy, and banana farm sectors on the RA report.

•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.

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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

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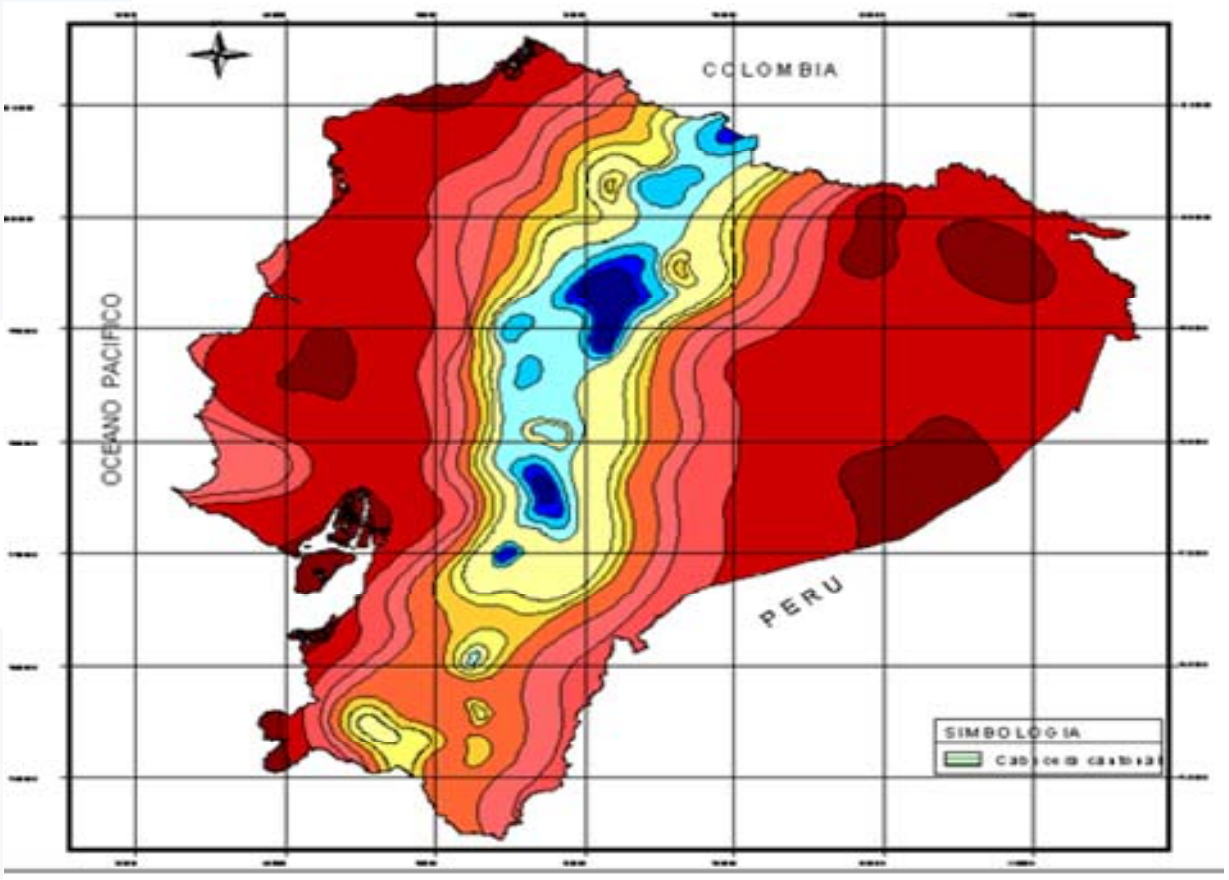
Multi-Annual Isotherm Map



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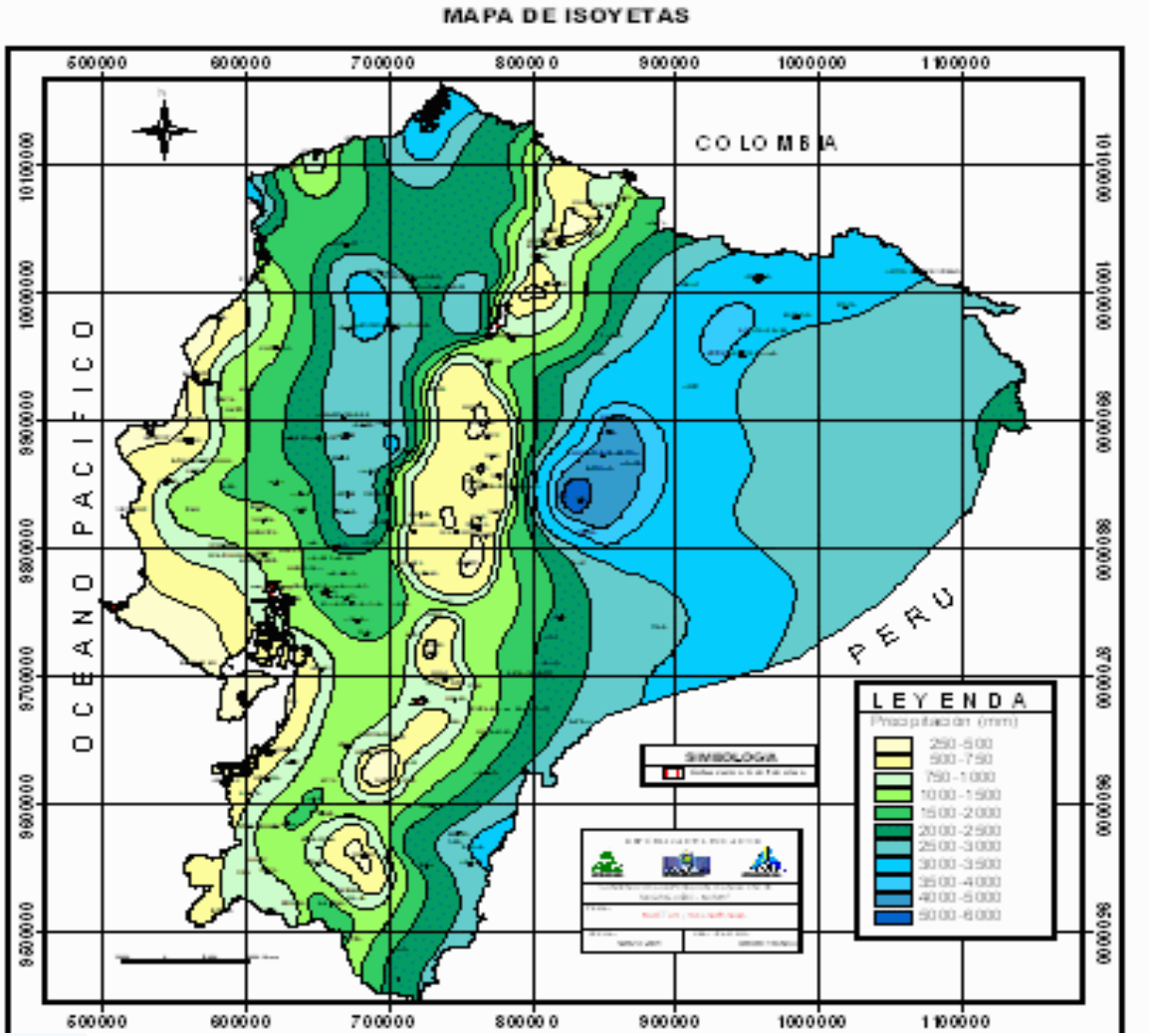
Isohyet Map



Source: Instituto Nacional de Meteorología e Hidrología (INAMHI)

Climate issues

•Due to the presence of the Andes and the ocean influence, Ecuador's climate varies from region to region.

•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.

1.Subsector Specific Results from Palm Oil Processing Plants

•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, These areas include West, East, San Lorenzo, in Esmeraldas Province and also in Guayas Province.

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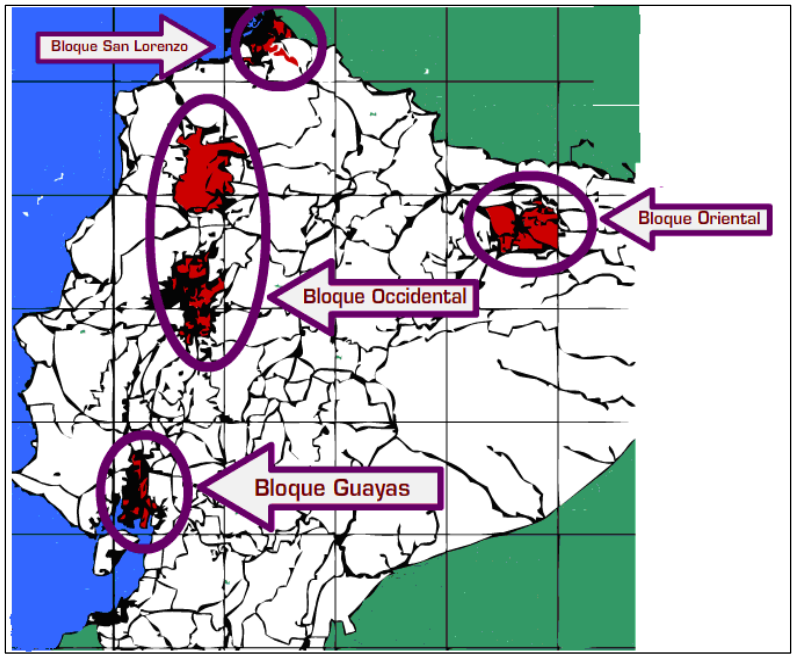
Refineries

- 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,

Palm Growers Location



Source: FEDAPAL

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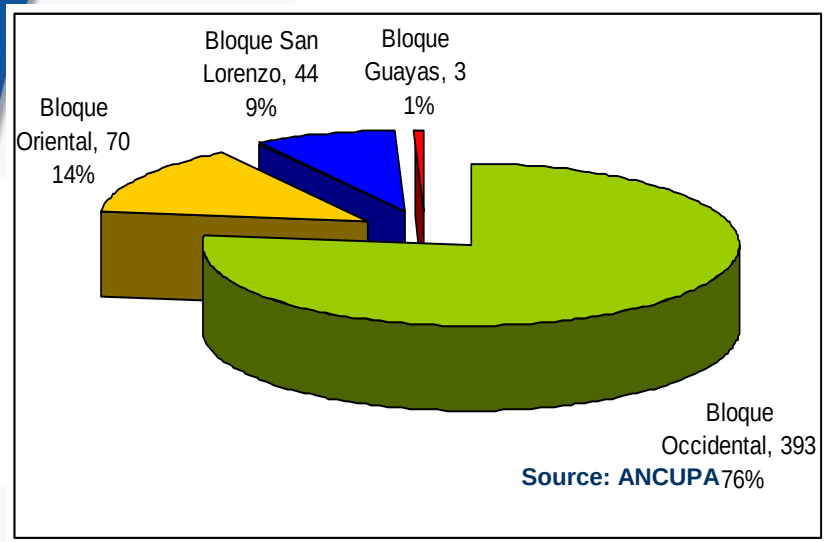
Palm Oil Extraction Capacity Per Area



- There are 33 plants in operation in the West. All plants in the East /3) and in San Lorenzo are operational, and one plant in Guayas is operational.

- 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.

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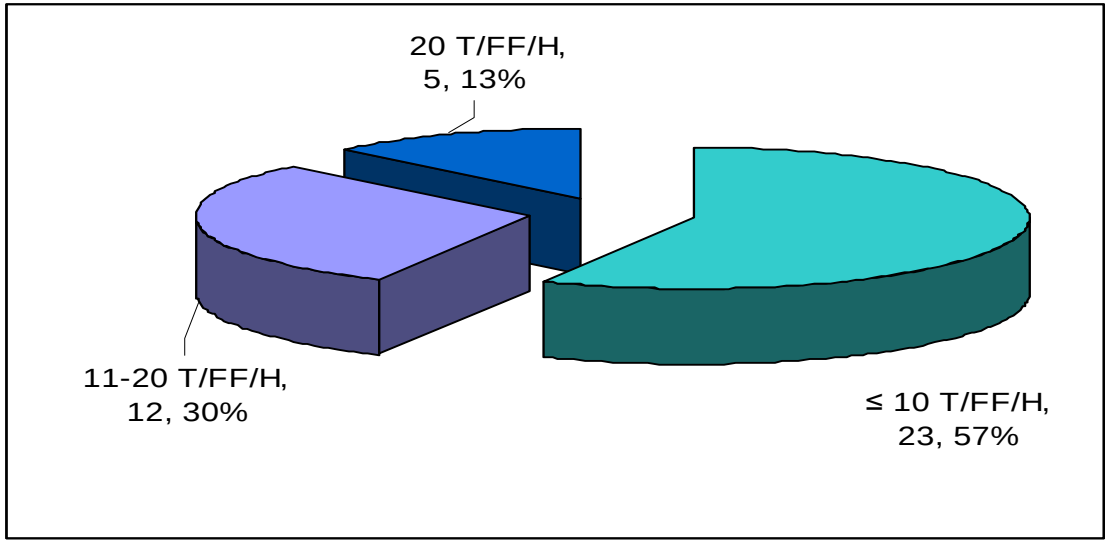
Stratification of Palm Oil Extraction Plants Per Size Category



- 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).

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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

•Liquid residues coming from African palm processing are oily compounds containing solids in suspension and a high content of organic matter.

•More than 90 percent of the palm oil extracting plants is treated in oxidation lagoons.

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

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2. *Subsector specific results from the sugar mills*

•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 is about 110,000 Ha, used mainly for sugar manufacturing and the remainder for production of “panela” (compact brown sugar) and alcohol.

•Harvested surface for sugar production (2006) about 69,156 Ha, with 89 percent of 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. This increase may be accentuated in future years due to the expected use of ethanol as fuel.

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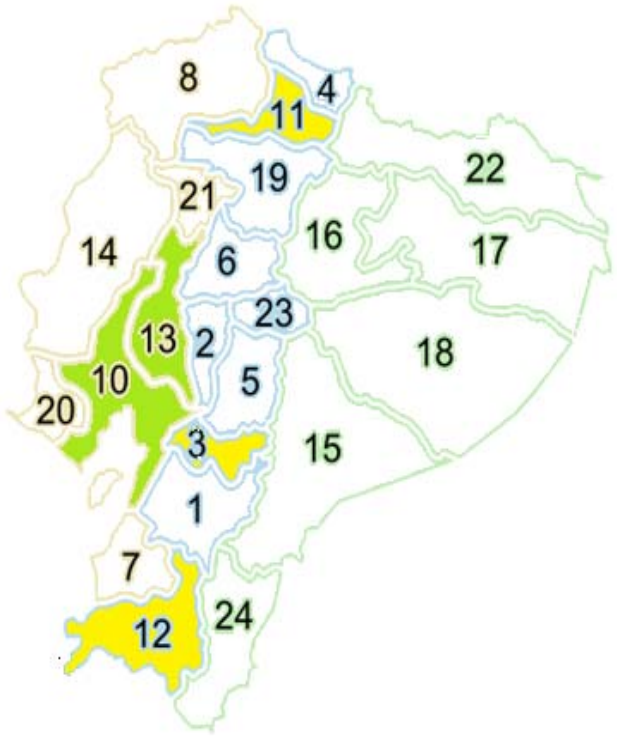
Main sugarcane producing provinces in the Lower Basin of Guayas and in the Sierra.



	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

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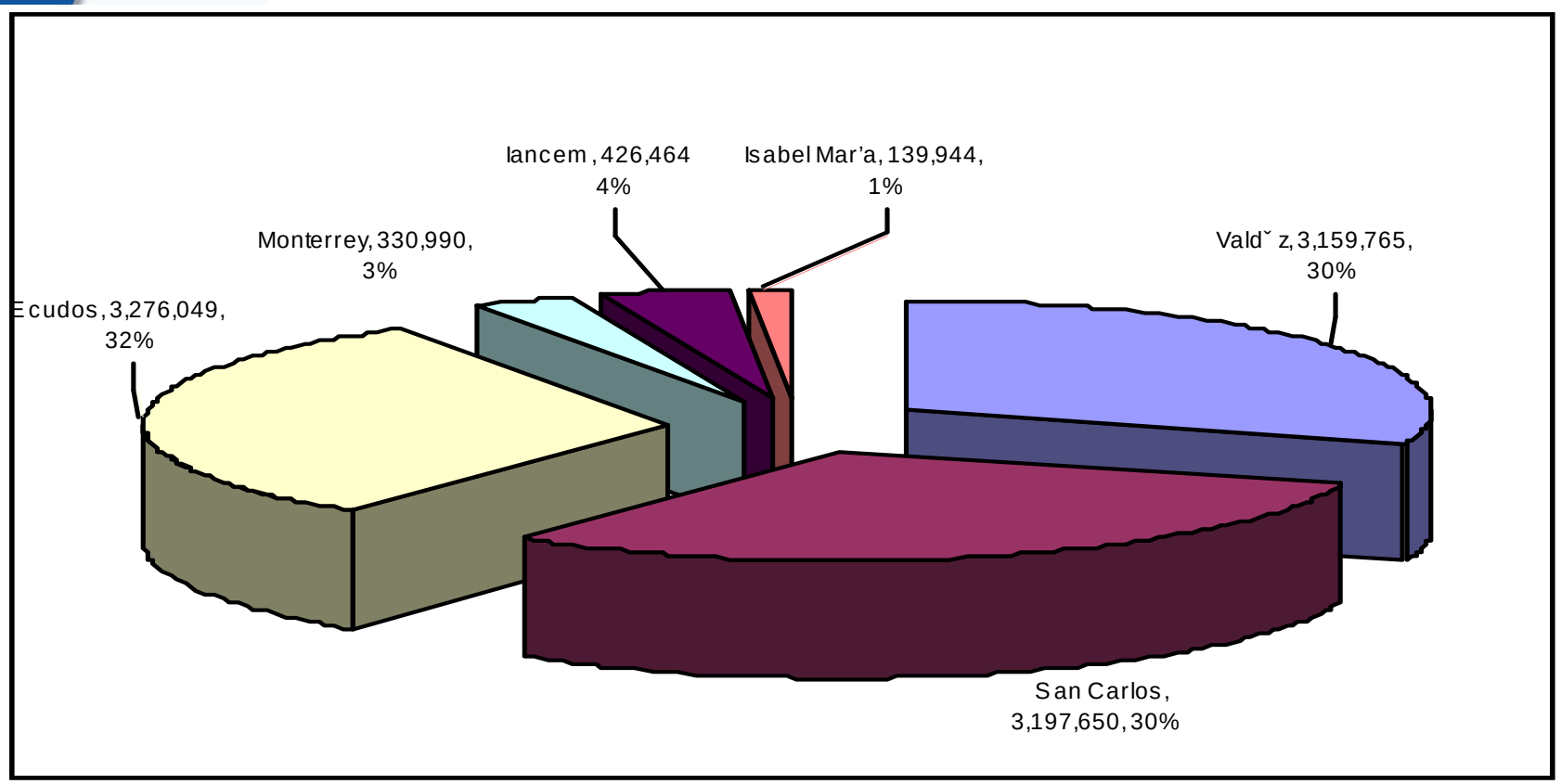
Size of Refineries in 2005–2006, Production of 50 kg Sugar Sacks



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- The refineries Ecudos, San Carlos, Valdéz, and Isabel María, start harvesting in July and continue until December, with 24-hour milling processes and an inter-harvesting time (machinery maintenance) between January and June.

- In the refineries Iancem 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.

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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,
•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.

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 Valdez

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

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3. Subsector specific results from the Alcohol Distilleries

- The installed capacity of the alcohol producer sector is estimated at 160,000 L/day, or 47,107,000 L/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.

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, Guayas Province, 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,

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- 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.

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Specific information on Distillery Codana, visited during the field trip

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

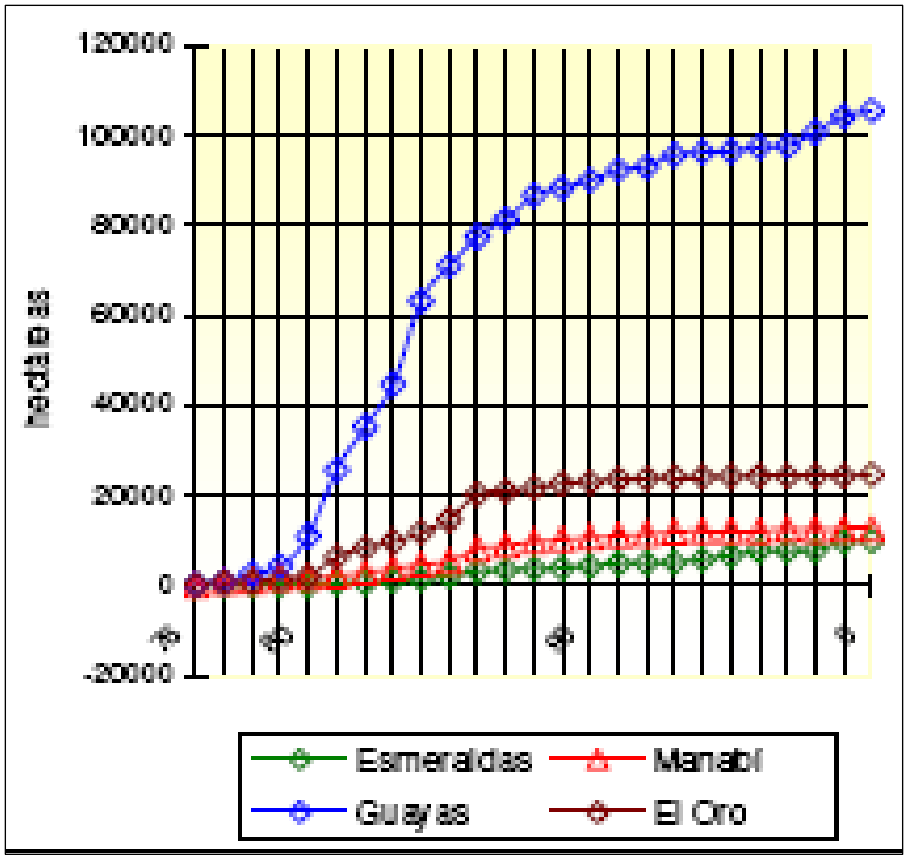
Picture 1: Distillery slops entering lagoon #1

Picture 2: View of Lagoon #1

Picture 3: View of UASB system (not operating) by the time of the field visit

4. Subsector specific results from the Shrimp Processing

Hectares of Shrimp Pools per Province 1976–2000



Source: POPAE, DGP, 2003

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•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 up to date.

•Shrimp obtained during farming and fishing are taken to the shrimp processing plants (packaging companies).

Year	Exportations	
	Million Pounds of Shrimp	Million Dollars (US)
2000	82,9	$297,4
2001	99,8	$280,6
2002	103,0	$263,8
2003	126,7	$303,8
2004	158,4	$350,1
2005	212,5	$480,2
2006	264,3	$597,6
2007	273,1	$582,0
2008	294,7	$673,4

Source: CNA, 2009

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Most shrimp packaging companies are located in Guayaquil and its surroundings. There are 18 plants that are the most recognized at the national level

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.

•Storage of the packaged product in refrigerated warehouses, from which they are transported to the shipping port.

POTENTIAL FOR 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.

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.

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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 Sugar mills: Used 2005–2006 sugar production; IPCC default values for W and COD; no offsets because use bagasse Distilleries: Used yearly average production; W and COD values of Codana Shrimp processing: 50% of the plants use lagoons
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	
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	
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	

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•Remarks about indirect emission.

•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.

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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.

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Methane to Markets

•Potential uses of the biogas in each of the sectors.

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

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Fuel Replacement Offsets

- 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 other plants (6 percent).

The fuels used by the thermal plants are natural gas, diesel, and fuel oil.

Methane to Markets

Carbon Emissions by Type of Fuel

Fuel Replaced	CO_2 Emission Factors
Generating electricity – depends on fuel mix	
100% coal	1.02 kg/kWh from CH_4
100% hydro or nuclear	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

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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

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