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Case Study on GHGs Mitigation by the Renewable Energy Utilization of Organic Wastes at Marikina River Basin (MRB) in the Philippines

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ABSTRACT

This case study was worked out as part of the project "Restoration of Ecosystem Service and Conservation of Carbon Sink in the Marikina River Basin in the Philippines". Especially, it focuses on abating GHGs emissions and generating renewable energy through methane waste management in the region. The general information was collected through a literature review and then, the local situation was identified through meetings with local stakeholders. In addition, the field survey was conducted to investigate the operation of renewable energy production facility through biogas from biodegradable organic waste. Based on the site survey results, the most applicable technologies and facility designs was studied. The proposed prototype model can produce 882 Nm^3 / day biogas (55% methane) using 15 m^3/day swine slurry and 5 m^3/day food waste. Biogas are used to generate 1,611 kWh of electricity a day through engine development. Considering that 20 m^3/day of swine slurry and food waste can be reliably handled, about 322 households will be able to use their own electric energy. On the other hand, there is a GHGs effect of 3,611 tCO_{2eq}/year. Given the characteristics of MRB's household and livestock waste emissions, the proposed prototype model can be spread throughout the Philippines.

Key words: *Green climate fund, Organic waste, Anaerobic digestion, Renewable energy, Marikina river basin*

1. Introduction

Marikina River Basin (MRB) region in the Philippines is a huge river basin comprising of 69,826 ha near the Metro Manila (Berkman, 2015). It is currently experiencing urbanization in line with rapid population growth. As a result, inconsistent land use management is destroying ecosystem services in the region. The decline of ecosystem service has made this region very highly vulnerable to climate change. There is rising trend in occurrence of floods and water induced disasters such as landslide within and in the lower catchments of the basin (Berkman, 2015). Recently, the need of ecosystem based adaptation and mitigation to the impacts of climate change is rapidly emerging in MRB. It is critical to reduce the vulnerability of ecosystems and increase the resilience to climate change in order to maintain sustainable management, conservation, and restoration of ecosystems in the region (Cruz, 2018).

Livestock production has rapidly expanded in many Asian countries during the last decades in response to rising demand for animal products due to increasing population and urbanization. This expansion is expected to continue and will increase the demand for land to produce high-quality feeds and forages. Consequently it accelerates the production and accumulation of animal wastes. Livestock waste is very beneficial for plant growth, improving soil structure and increasing soil fertility. If used properly, it can replace a significant amount of chemical fertilizers. However, if animal manure is not carefully managed to minimize emissions, it becomes a source of Greenhouse Gases (GHGs) emissions

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and furthermore a direct threat to human. In manure, carbon in the form of CH_4 and nitrogen in the form of N_2O are 21 and 310 times more harmful than CO_2, respectively, in causing the Global Warming Potential (GWP).

In the MRB, waste is the largest source of GHGs emission (6,521 Gg CO_{2eq}, 81.6%). This figure is very high compared to 56% share of the GHGs in waste of national GHGs inventory (Buendia and Lasco, 2019). The amount of emission in rest of the sector is very small. The emissions of the Land-Use and Land-Use Change and Forestry (LULUCF) sector is approximately 73 Gg CO_{2eq} (Buendia and Lasco, 2019). The national LULUCF sector is a carbon sink, while the deforestation and land use changes in the region over the last decades have made LULUCF as source of emissions. Most of the waste from MRB comes from household waste and agricultural waste (livestock and crops/plants) at residential/settlement areas (ADB $_{(c)}$, 2013). Most of these are biodegradable waste, which accounts for an average of 50% of waste. Of the total GHG emitted from livestock, CH_4 produced from enteric fermentation had the highest percentage (60%) which largely came from ruminant animals like swine, carabazo, cattle, and goats. The remaining 40% came from emissions of CH_4 and N_2O from the management of the animal manure (Buendia and Lasco, 2019).

The problem of waste disposal in MRB has been rising as an urgent problem for mitigation of climate change. This case study focuses on reducing the increase of GHGs from livestock and household biodegradable waste accumulation in residential areas of the MRB and furthermore on establishing ways for sustainable development through generating renewable energy by organic waste management in the MRB region. The objective of this case study is to develop the prototype model for biodegradable waste management from both household and livestock (especially swine manure) in Municipalities (Antipolo City, Baras, Tanay, Rodrigues, San Mateo) at MRB.

2. Status of survey area

2.1 Biodegradable organic waste from livestock

The Philippines' agriculture, hunting, forestry and fishing (AHFF) sector accounted for 7.1% of the total GDP (PAS $_{(a)}$, 2019). Livestock production reached 17.75% in total agricultural output and increased by 3.22% in the second quarter of 2019 (PAS $_{(b)}$, 2019). As meat and milk consumption increase, programs that promote livestock productivity are a key part of the government's mid-term plan. Livestock industry in the Philippines is showing positive growth due to the increase in meat demand resulting from improvement in the national economy (PSA $_{(b)}$, 2019). Meat consumptions are expected to increase as a result of the rapidly increasing Philippine population. As a consequence, CH_4 and N_2O emissions from enteric fermentation and manure management are expected to increase with the increasing demand for livestock products (Buendia and Lasco, 2019).

As fig. 1 shows, swine population continues to grow considerably from 3.8 million heads in 1950 to as high as

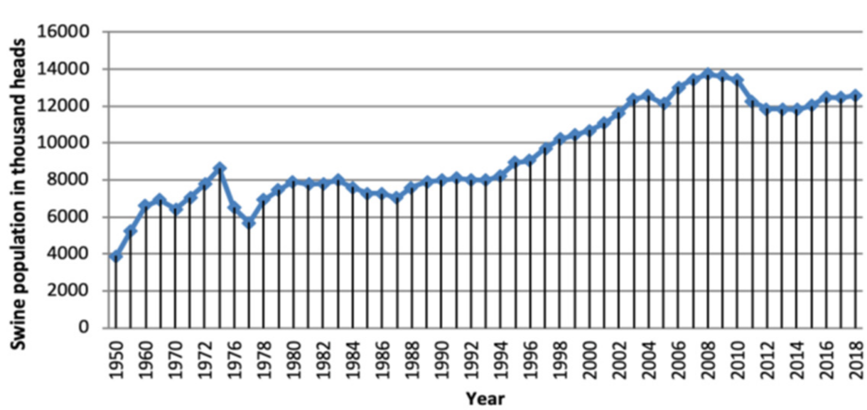

Fig. 1. Swine population from 1950 to 2018 (PSA (c),2019).

13.7 million heads in 2008 (PSA $_{(c)}$, 2019).

As of July 2019 (PAS $_{(c)}$, 2019), the total inventory of swine was estimated at 12.53 million heads, representing a decrease of around 9% compared with its previous year's stocks heads. Population of swine in backyard farms of 8.06 million heads contracted by 1.2% from the previous year's count heads. On the other hand, stocks in commercial farms at 4.68 million heads expanded by 0.4% from the previous year's heads (PAS (c), 2019). Among the regions, Central Luzon recorded the highest swine inventory of 2.14 million heads. This was followed by Calabazon (5 Municipalities: Antipolo City, Baras, Tanay, Rodrigues, San. Mateo belongs to Calabazon) with stocks of 1.55 million heads. The combined stocks of these 2 regions accounted for 29.5% of the country's total swine inventory (table 1).

As the production systems that concentrate livestock animals in confinement are becoming popular, the swine and poultry farms have produced significant amounts of animal waste. The key issues and features of each Local Government Unit (LGU) were identified at stakeholder meetings as follows. LGU Antipolo City will provide incentives to farmers that plan to relocate to the designated agro-industrial area in Pinugay. Centralizing infrastructure support facilities makes it easier for LGU to monitor small-scale farmer and supply them with incentives and other support packages for their expansion. At LGU Tanay, septic tanks must be installed for raising pigs in the watershed (more than 100 ha). They would also need to have a Pollution Control Officer (PCO) assess their discharge. Otherwise, for every 2 units of pigs, they would be required to secure a discharge permit worth PhP 3,000 (55 US$). In LGU Baras, because toxic human waste coming from the watershed reaches Laguna de Bay and eventually Manila Bay, it is critical issue to protect Manila Bay. Table 2 is the current status of piggery

Table 1. Amount of swine waste by region in the Philippines (2018)

Region	Swine (number of head)			Swine Waste (m^3/year)		
	Backyard1	Commercial[2]	Total	Backyard	Commercial	Total
CAR	205,550	3,854	209,404	195,817	7,174	202,991
Ilocos Region	442,735	114,623	557,358	421,771	213,371	635,142
Cagayan Valley	409,246	36,552	445,798	389,868	68,042	457,910
Central Luzon	554,495	1,590,066	2,144,561	528,240	2,959,908	3,488,148
Calabarzon	377,760	1,176,748	1,554,508	359,873	2,190,516	2,550,389
Mimaropa	458,824	122,042	580,866	437,099	227,181	664,280
Bicol Region	790,092	163,629	953,721	752,681	304,595	1,057,277
Western Visayas	660,272	83,888	744,160	629,008	156,158	785,166
Central Visayas	566,513	204,299	770,812	539,689	380,303	919,991
Eastern Visayas	307,136	13,094	320,230	292,593	24,374	316,968
Zamboanga Peninsula	515,746	12,638	528,384	491,325	23,526	514,851
Northern Mindanao	593,700	381,324	975,024	565,588	709,835	1,275,423
Davao Region	766,840	144,775	911,615	730,530	269,499	1,000,029
Soccsksargen	450,963	318,383	769,346	429,610	592,670	1,022,280
Caraga	215,662	11,110	226,772	205,450	20,681	226,132
Armm	43,072	-	43,072	41,033	-	41,033
NegrosIsland Region	698,548	93,170	791,718	665,472	173,436	838,908
Total	8,057,154	4,470,195	12,527,349	7,675,648	8,321,268	15,996,916

(PSA (c),2019)

(hog/swine) farms of each municipalities discussed at the stakeholder meeting in Manila, on Sept. 2018[3].

2.2 Amount of biodegradable organic waste in study area

"Owned manually flushed" is the most popular type of toilet used by the respondents[4] in five municipalities covered by MRB (ADB $_{(b)}$, 2013). In Antipolo City, 86% of the respondents claimed to have this type of toilet. In Rodriguez, it was mentioned by 81% of the total respondents. In the remaining 3 municipalities: Tanay, Baras and San Mateo, this type of toilet comprised 80% of the total responses received. The remaining 14-20% of the total responses is shared by the other types of toilet present in the municipalities such as the flush system, communal manually flushed, buried, open pit and open defecation (ADB (b), 2013). There are more respondents who said that their wastes are biodegradable as compared to those who indicated that their refuse are non-biodegradable although their ratio varies with municipality (ADB $_{(b)}$, 2013). Broken down as: Antipolo City-55% (biodegradable) / 31% (non-biodegradable); Baras-55% (biodegradable) / 30% (non-biodegradable); Tanay-67% (biodegradable) / 33% (non-biodegradable); San Mateo- 55% (biodegradable) / 45% (non-biodegradable) and Rodriguez-43% (biodegradable) / 50% (non-biodegradable); Average waste generation per household per week was Tanay (2.99 kg), Antipolo (2.69 kg), San Mateo (2.19 kg), Baras (2.03 kg), Rodriguez (1.94 kg). Over-all MRB was 2.18 kg per household/week (table 3).

3. Applicable Biogas Technologies Study

3.1 Biogas Technologies

The purpose of this study is to establish a system to mitigate GHG effects through recycling of energy and nutrients from swine wastes and household biodegradable waste as an important component of the national efforts on minimization of GHGs in the Philippines. The anaerobic digestion technique producing methane gas from strong organic wastes is the production method of alternative energy substituting fossil oil and the very effective disposal method of organic wastes reducing GHG.

Anaerobic digestion (AD) is a naturally occurring biological process that uses microbes to break down organic material in the absence of oxygen. In engineered anaerobic digesters, the digestion of organic waste takes place in a special reactor, or enclosed chamber, where critical environmental conditions such as moisture content, temperature and pH levels can

Table 2. Livestock farms status in this study areas

Municipality	Status
Antipolo City	There are small and large-scale famers both in the rural and urban areas. They include 9 major private livestock farms (5 piggery and 4 poultry farms) and 1 poultry-piggery farm in the city .
Rodriguez	The great amount of grazing land in the municipality has made possible the raising of both commercial and backyard cattle. There are abundant stock of livestock, especially commercial swine & chicken.
Tanay	People are engaged in hog raising activities in the watershed (more than 100 ha).
Baras	Swine is the most prevalent backyard farm animal. The most suitable place for raising swine is barangay Pinugay. To a much lesser extent, cattle is also raised, concentrated in Pinugay. Poultry is also raised in backyards but is not sold outside the households.

(LGU Stakeholder's Meeting in Manila, Sept. 2018).

[1]Backyard Farm: any farm or household which raises at least one head of animal as either farming or non-farming and does not qualify as a commercial farm.
[2]Any livestock farm which satisfies at least one of the following conditions: 1) Tending at least 21 heads of adult and zero head of young animals , 2) Tending at least 41 heads of young animals, 3) Tending at least 10 heads of adult and 22 heads of young
[3]A stakeholder meeting was held in Manila on September 28, 2018, and issues and challenges on climate change were discussed within the MRB. About 30 people attended, including LGU Rodriguez, Antipolo City, Baras, San Mateo and Tanai.

be controlled to maximize gas generation and waste decomposition rates. One of the by-products generated during the digestion process is biogas, which consists of mostly methane (ranging from 55% to 70%) and CO_2. The benefit of an AD process is that it is a net generator of energy. From the energy produced by the AD facility, depending on the technologies, only maximum of 15% is required for the AD facility itself. The level of biogas produced depends on several key factors including the process design, the volatile solids in the feedstock (composition of the feedstock) and the Carbon/Nitrogen (C: N) ratio. The mostly used AD technologies which fit for several biomass production are broadly defined as bellows (table 4).

3.2 Technology proposal: Semi dry anaerobic digestion (Plug & flow reactor)

This process has been studied to treat a biomass with a content in solid waste of 15-20%. The plug & flow reactor (PFR) gives the advantage to have a smaller reactor with a reduction in the investment costs because solid waste is directly utilized as the process input materials without water dilution (table 5). The system need to work with very viscous material. The equipment is more expensive than the wet AD.

On the other hand, the dry AD does not need many pre-treatments. The waste are not diluted. The only pretreatment is a screening to take out the junk materials over

Table 3. Total amount of biodegradable organic waste generated from municipality

Municipality	Biodegradable organic waste	Non-biodegradable waste	Discharging unit (kg/household/week)	Population (Persons)	Household (Ea)	Biodegradable organic waste	
						(ton/year)	(ton/day)
Antipolo City	55%	31%	2.69	248,327	51,735	7,257	19.88
Baras	55%	30%	2.03	7,396	1,580	167	0.46
Tanay	67%	33%	2.99	3,505	769	120	0.33
San Mateo	55%	45%	2.19	4,080	680	78	0.21
Rodriguez	43%	50%	1.94	81,928	14,762	1,493	4.09
Total	-	-	-	345,236	69,526	9,115	24.97

(ADB $_{(b)}$, 2013)

[4]A total of 300 respondents were proportionally surveyed at 2015.

Table 4. Anaerobic digestion technology

Criteria	Types of plant	Features
Thermal Process	Psicrophilic	20°C
	Mesophilic	35-40°C
	Thermophilic	55-60°C
Percentage of solids in the Process	Wet digestion	5-8%
	Semi dry digestion	8-20%
	Dry digestion	> 20%
Biological Phases	Single phase process	All chemical processes occur in the same reactor
	Separate phase process.	Hydrolytic phase and the fermentative (acid organic) phase occurs separate from the methane organic phase
Operational mode	Reactor in continuous	Material is mixed with a plug-flow system
	Reactor in batch (non-continuous)	Material is not mixed inside the cells

40 mm. Because the loss of material is very low, the system works better with biomass coming from source sorting collection. Due to the viscosity of the material the reactor does not use CSTR but pistons plug-flow which have a simplified but stronger mechanic.

4. Feasibility results

4.1 Basic design of biogas production plant

1) Input capacity: 20 m^3/day
2) Digester capacity: 600 m^3 (HRT 30 days)
3) Process temperature: 38°C
4) Input design: 20 m^3/day (swine waste 15 m^3/day, household biodegradable waste 5 m^3/day)

4.2 Pilot project plan as feasibility test

Commercial swine farm will install an anaerobic digester of 20 m^3/day input scale and a co-generating system of 80kW for commercializing use. The anaerobic digester is capable of producing biogas about 882 Nm^3/day, and the co-generating system can convert the produced biogas to the electrical power of 1,611 kWh/day. Also the estimated amount of produced energy and mitigated CO_2 were 4,197 Mcal /day and 2,034 ton tCO_{2eq} /year respectively (Table 6).

In addition to the GHG mitigation effects through bio-gas power plants, the calculation of the reduction amount of GHG

Table 5. Advantages and disadvantages of AD technologies

Criteria		Advantage	Disadvantage
Wet (CSTR)	Technologic	- Good knowledge of the process (due to previous use for sludge) - It can work mixing also waste water from different process (cow farms)	- Short circulation hydraulic - Non homogeneous material, heavier stay on the bottom and the lighter is floating. - Abrasion of the mechanical parts due to sands and inert material. - Complicate pretreatment.
	Biologic	- Dilution of concentration and dilution of the hazardous waste	- Loss of organic matter during the pre-treatment
	Economical & Environmental	- Pumping and mixing system available easily on the market	- High investment costs - High waste water production form the process
Semi-dry (PFR)	Technologic	- Waste pumping system easy to be found on the market - Less pre-treatment (especially using material collected from source sorting collection)	- Non homogeneous material, heavier on the bottom and lighter on the top - Abrasion of mechanical parts
	Biologic	- Less concentration of hazardous waste	- Loss of organic matter during the pre-treatment
	Economical & environmental	- Pumping and mixing system less expensive	- High investment costs - High waste water production from the process
Dry	Technologic	- No need of mixer or stirring systems - Resistance to heavy inert	- Bio waste with a reduce rate of organic matter cannot be treated alone - High tech equipment and maintenance is needed - Small size waste only
	Biologic	- No loss of organic matter in the pre-treatment - High OLR(Organic loading rate)	- Small dilution to reduce the negative effect of hazardous waste
	Economical & environmental	- Small pre-treatment - Smaller dimension of the reactor - Small use of water - Less costs for heating the reactor	- High investment costs

Table 6. Estimated organic waste input, biogas production and GHG mitigation at the project Site

Facility facts	unit	Description	Values
Piggery slurry	heads	Breeding head number	3,000
	L/head/day	Discharging unit	5.10
	%	Organic content(VS)	3.00
	m^3/day	Total amount	15
	kg/day	Organic amount	459
Household biodegradable waste	m^3/day	Collecting amount	5
	%	Organic content(VS)	16.00
	kg/day	Organic amount	800
Total organic material	m^3/day	Input amount	20
	kg/day	Input organic amount	1,259
Biogas	Nm^3/day	Biogas production(55%CH4)	882
	Nm^3/day	Methane production	485
	Mcal/day	Energy production	4,197
Electric power	kW	Electric generator	67
	hr/day	Operation time(average)	24
	kWh/day	Electric power production	1,611
Household	kWh/day	Electric consumption	5
	households	Energy self-satisfactory house	322
GHG mitigation	tCO_{2eq}/year	CO_2mitigation	2,034

Table7. The estimation of GHG emissions reduction

Items	Unit	Values
Biogas plant mitigation	tCO_{2eq}/year	2,034
Treatment amount(pig slurry + household organic waste)	m^3/year	7,300
GHG emission unit (baseline: composting)	$kgCO_{2eq}/m^3$	216
Amount of GHG emission(baseline: composting)	tCO_{2eq}/year	1,577
Total GHG mitigation	tCO_{2eq}/year	3,611

is taken the effect of efficient management of livestock manure into account. This supplementary opinion will be based on the LCA methodology after surveying the status of the disposal of existing organic wastes in the actual project area. A procedure is required to assess GHG emissions. In our case of the assessment, baseline was placed in composting to yield additional GHG emissions (table 7).

Regarding bio-gas development using household waste, the validity result was supplemented by reviewing the applicability of the household waste level. This issue seems to have been caused by the fact that household waste has occurred in a distributed manner, which makes it difficult to collect it. In case that it is difficult to collect household waste, food waste, etc., it is possible to consider the introduction of the by-products (e.g., slaughtering residues, etc.) from food processing plants.

5. Conclusions

This case study focused on generating renewable energy and abating GHGs emission through organic waste management at MRB region in the Philippines. The proposed prototype model can produce 882 Nm3 / day biogas (55% methane) using 15m3/day swine slurry and 5m3/day food waste. Biogas are used to generate 1,611 kWh of electricity a day through engine development. Considering that 20 m3/day of swine slurry and food waste can be reliably handled, about 322 households will be able to use their own electric energy. On the other hand, there is a GHGs effect of 3,611 tCO_{2eq}/year.

In addition to greenhouse gas reductions, this case study of producing renewable energy from biogas from wastes suggests effective mitigation measures to cope with climate change with sustainable development. Given the characteristics of MRB's household and livestock waste emissions, the proposed prototype model is likely to spread throughout the Philippines.

As mentioned, concept note on “Restoration of Ecosystem Service and Conservation of Carbon Sink in the Marikina River Basin in the Philippines” was submitted to the GCF by KEITI. Regarding GHGs Reduction and Renewable Energy Generation through Methane Waste Management, the summary of its technical and financial feasibility was attached for review. Once the concept note has been approved in accordance with GCF's procedures, a formal business plan should be developed. The consultations with the LGU will be made to determine the site where the pilot project will be implemented. A negotiation with the LBP is going to be planned for financial framework. For the biogas production plant, the design and construction possibility of Korean domestic companies will be reviewed.

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