Final Report

Project Reference Number: LCI2012-03NMY(R)-Lopez

March 2012 - February 2013

Assessment of Carbon Sequestration through Vermitechnology in Organic Farming

Low Carbon Initiatives Framework

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Detailed activities based on timeline for Year 1 (2013-2014)

Background

APN Project LCI2012-03NMY(R) – Lopez is a multidisciplinary collaboration which attempts to find out how vermitechnology contributes to climate change. The project concept was circulated to the prospective collaborators to co-develop and implant their areas of interest and submitted for APN funding in 2012. The partner universities are University of the Philippines Visayas, University of Science-Vietnam and Hanyang University-Korea. The project leader and partner from Vietnam are university-based educators and researchers in the fields of soils, agriculture and genetics, while Hanyang University is represented by a contracted freelance scientist highly specialized in earthworm identification work.

The research project works on the premise that carbon sequestration from soil organic matter is directly proportional to a net reduction in greenhouse gases (Drinkwater et al 1998, Mader et al 2002, Pimentel 2005, Reganold et al 2001). Soil is the major but manageable resource of the planet's atmospheric carbon sinks. When this is combined with the advantages of biological waste processing via earthworm activities to produce an organic fertilizer, we get joint potential benefits to redress climate change, reduce pollution and ensure food security. The contribution of carbon in the soil to climate change mitigation has been addressed in various studies. However, this is an area that has not been focused in the Philippines where organic farming method is being mandated since 2010. To provide a holistic view of the carbon flow in an organic farming system, this project covers the assessment of carbon flow which starts from the transformation of organic matter in the vermicomposting unit until the organic matter in the form of vermicompost is utilized to improve the physical structure of the soil or a source of plant nutrients. Vermicomposting is a technology widely adopted in organic farming in the Philippines today.

Vermitechnology particularly vermicomposting is a low-input waste management technique using earthworms (< Latin *vermi*) to process biodegradable farm and domestic wastes into vermicast or vermicompost. Materials that undergo biological digestion through the earthworm gut are excreted as vertices. While a mixture of the cast and the biologically decomposed organic matter in vermicomposting is called a vermicompost. Innovations in vermitechnologies have increased during the last two decades. Examples are variations in substrate type and proportion, processing vermicompost-derived foliar nutrient formulas, and variations in production design at different scales. Possibility of a commercial-scale production of earthworms to serve other uses such as for food, feeds and medicinal or therapeutic purposes have been explored. National in scope but with regional implementation, the National Vermimeal and Vermicompost Production Project in 2008 funded by JICA through NEDA, involved universities and colleges throughout the Philippines to put-up vermicomposting units for research and production purposes. The medicinal uses of earthworms have been published or presented (Ang Lopez and Alis, 2005; Zhenjun, 2003; Nguyen and Ho Huynh, 2013). Studies on food and feed value (Ang Lopez, 2004, 2009; Guerrero, 2005, Zhenjun, 2003) and other relevant interests on earthworms and vermicomposting were also presented during the International Symposium in Vermitechnologies (ISVT) held in the Philippines twice, in 2009 and 2013. ISVT3 was co-organized by APN Project LCI2012-03NMY(R) – Lopez.

Vermicompost or vermicast is valued for its slow nutrient-releasing action, as a source of plant growth promoting substances and effective microorganisms that promote mineralization of the locked-up nutrients in organic matter and mineral soils. The favorable function of vermicast or vermicompost have been attributed to its passage through the earthworm gut which is known as a biodigester. Thus, the application of vermicompost imparts into the soil its microbiological, physical and chemical properties that enhance fertility and productivity. Vermicast resembles a stable organic matter that can promote the sequestration or storage of carbon. However, contrasting views on the role of earthworms in the reduction of greenhouse gases through the stimulation of carbon sequestration has been raised recently. While it was once suspected that earthworms stimulate carbon sequestration in the soil, which helps reduce greenhouse gas emissions, a team of researchers from Europe, the United States, and Columbia compiled the results of nearly 60 studies and found an increase in nitrous oxide emissions by 42 percent and carbon dioxide emissions by 33 percent through earthworm activity in the soils (Nature Climate Change, 2013 doi: 10.1038/nclimate1692). More application of organic matter and organic fertilisers can provide more food for earthworms, and the moving away from conventional land tillage or cultivation could also boost their number. Earthworms increased the global warming potential of soils by 16 per cent overall and although earthworms are largely beneficial to soil fertility, they increase net soil greenhouse-gas emissions according to Lubers (2013).

Since earthworms play an essential part in determining the greenhouse-gas balance of soils worldwide, more experiments that include growing plants, as well as more long-term studies and more field studies are needed to fill-in the information gaps on what extent global worming can lead to global warming. Greenhouse gas emissions from the agriculture sector are responsible for approximately 30% of all emissions, come from anthropogenic sources (Tubiello et al., 2013). Nearly half of all the GHG emissions from agriculture are accounted due to methane and nitrous oxides because of the use of synthetic fertilizers, and the interaction of soil organic matter and soil biota and about 20 per cent of global carbon dioxide emissions and two thirds of nitrous oxide emissions come from soil (Nature Climate Change, 2013 doi: 10.1038/nclimate1692). Emissions from the soil come from a number of natural biological processes involving plant roots and the microorganisms that live in the ground. In the United States, 15% of all GHG emissions from agriculture are accounted by manure management alone (Environmental Protection Agency [EPA], 2014). Cattle manure and fruit and vegetable wastes are commonly utilized as composting agents for quality composts used for agriculture (Risse and Faucette, 2012).

The application of vermicomposting or vermicast in soils may further contribute to faster carbon and nitrogen mineralization resulting to increase in emission of CO_2 and N_2O. Earthworms could play a major role in CO_2 and N_2O emission because they affect the physical structure of the soil by burrowing, making it more porous, and with their interaction with microbes that produce biogenic carbon dioxide. In contrast, nitrous oxides are produced in earthworm's microbial-rich guts and the anaerobic patches in the soils.

Emissions from a vermicomposting system must be part of the inventory of carbon pathways. In a vermicomposting system, the emission of biogenic carbon dioxide may be enhanced because of the larger population of earthworms and microorganisms, and enhanced earthworm-microbial synergies. The pre-digestion phase in vermicomposting can possibly create an anaerobic patches conducive to the production of CH_4 and N_2O.

In Year 1, controlled measurements of CO_2 and N_2O from a bin-scale vermicomposting system was conducted for benchmarking. Also included in this experiment was the trial of the gas collection and gas measurement method designed for small-scale and field applications. The focus of this research is timely and relevant to the low-carbon initiatives in the climate change program and serves the interest of several sectors, primarily the organic and vermitechnology adoptors and research.

Generally, this research project aims to assess the carbon budget, and estimate greenhouse gas emission within a vermitechnology-based organic farming system. The research project would like to answer the following:

- Is a vermitechnology-based organic farm more resilient to climate change because of enhanced carbon storage?
- What is the relationship between earthworm species/population and Soil Organic Carbon (SOC) and its storage?
- What are the spatial and temporal aspects in vermitechnology affecting resiliency to Climate change?
- Is there an economic value or carbon credit in vermitechnology-based farming operation?
- What capacity or capability-building activities are needed to enhance knowledge and application of vermitechnologies to enhance carbon sequestration for climate change mitigation?

Objectives:

Specifically, the objectives of the research are the following:

1. To establish the Permanent Monitoring Sites (PMS) based on organic farming practices.
2. Determine organic carbon in soils and vermicompost.
3. Conduct earthworm population survey and identification, including DNA sequencing.
4. Measure GHG emissions (such as N_2O, CH_4 and CO_2) in vermicomposting.
5. Perform carbon inventory and estimate carbon footprint in organic system.

Funding: USD 45,000 for Year 1 (March 2013- February 2014)

Except for Activities 5.7 and 5.10 (please refer to Appendix A: Timeline for Year 1, 2013-2014), the rest of listed activities and events were covered in Year 1 funding . An experiment on the GHG collection and sensing for CH_4, CO_2 and N_2O in bin-scale vermicomposting and carbon mineralization trial were done not only to compensate for the Activities 5.7 and 5.10, but also to provide a broader account of the carbon flow. This came-about from the peer-review of the research methodology at UPV. The following were suggested for inclusion in the measurments:

1. Analysis of organic carbon x type of waste substrate with and without earthworms in vermicomposting bins or beds.
2. Development of gas collection and measurement protocol.
3 GHG emission measurements in vermicomposting bins or beds for baseline data.
4. Replication of measurements at the PMS scale.
5. Identify the vermicomposting methods of the PMS.

Justification on Activities 5.7 and 5.10: Information gathered in the trials in the Philippines prior to the conduct of the proposed Activity 5.7 Technology Transfer and Establishment of Permanent Monitoring Plots in Vietnam scheduled for November 2013 were insufficient because of unfinished gas measurements, soil and compost analysis and field resampling. Typhoon Yolanda caused flooding of fields at the PMS for several days and collapse of the vermicomposting units and monitoring set-ups. Likewise, the partners' orientation activities in October 2013 was moved to November 2013 to allow the partners to participate in ISVT3, and get broader perspectives of the vermitechnology research and application in the Philippines and other participating countries. At ISVT3, the Vietnamese partner also presented a paper on the "Medicinal Properties of Traditional Formula Using Earthworm in Vietnam". Conduct of Activity 5.10 was deferred several times because of the availability of the Project Leader and Partners. Finally, it was decided that the activity be postponed and become a start-off activity for Year 2. Nonetheless, through the web discussions about project progress and accomplishments went through between partners.

1. Criteria Setting for the Selection of Permanent Monitoring Sites

Using the criteria for organic certification in the Philippines (R.A. 10068, 2010) , the following criteria were set for the selection of the PMS:

1. A practicing organic farm for at least five years.
2. Produces vermicompost, vermicast, vermitea concoctions and other earthworm-based techniques as input to organic farming operation.
3. Certified by a third party certification in the Philippines that adheres to an organic farming integrity.
4. Agrees to be a PMS partner of the APN research.

For replication purposes, three sites were selected as PMS: Southern Tagalog (PMS1) and the Visayan regions (PMS2) and PMS3). Descriptions of the PMS are provided in Appendix B.

2. Schedule of sampling of soils and vermicompost, and earthworm survey

Sampling schedule was based on the two seasons in the Philippines such as:

February – April	peak of dry season
May- August	start of wet season
July - September	peak of wet season
October– December	end of wet season
January- February-	start of dry season

In Year 1 one hundred soil and compost, and about 60 earthworms were collected from the vermicomposting bins and field monitoring sites. These were sent to laboratories and analysed for physico-chemical and microbiological content. Sampling of soils and vermicompost in PMS1 were repeated thrice after typhoon Yolanda in November 2013 disrupted field measurements at PMS1 and some areas in PMS2 and PMS3. Two strong typhoons, Glenda in June and another one in August 2014 severely destroyed the vermicomposting production units in PMS1 including the monitoring set-ups.

The special techniques in earthworm sampling and preparation though simple, was time-consuming and needs some equipment and facilities that were not readily available. Access to the right computerized microscope with a camera was a problem and a proposal to purchase the equipment did not materialize due to financial constraints. Our remedial action was to request Southeast Asian Fisheries Development Center (SEAFDEC) in Tigbauan, Iloilo to allow us to use of laboratory facilities. Approval of our request enabled physiological identification of a few earthworm samples by Dr. Blakemore. Impediments in sending biological and agricultural samples for testing at the Soil-Food-Web facility in Oregon, USA were due to strict regulations in the Philippines as well as strict entry in the US. Except for the DNA sequencing work on earthworm tissues, all analyses were done in the Philippines such as microbiological analyses at the BIOTECH, UP Los Baños, chemical analyses at the Bureau of Soils and Water Management Laboratory in Quezon City, the Regional Soils Laboratory in Lipa City, Batangas, Sugar Regulatory Administration Soil Testing Laboratory in Negros Occidental, and the Chemistry Laboratory of the School of Technology, UP Visayas. The collected earthworm samples were stored at the National Institute of Molecular Biology and Biotechnology (NIMBB-UP Visayas). For technical reasons, attempts for DNA sequencing work to be done at NIMBB-UP Visayas and NIMBB-UP Diliman were unsuccessful. Hence, DNA barcoding was carried-out on earthworm extracts/tissues at Hanyang University Biological Laboratory in Seoul, Korea. Results of the analyses provided baseline information on earthworm species in the three PMS. With the acquisition of laboratory reagents and techniques, the work on earthworm identification barcoding received the interest of NIMMB at UP Visayas, hence will be continued work in future.

Information Generated in Year 1

Presented in this final Report are the partial data on Earthworms (Appendix C), benchmark Soil Organic Matter transformation in a microscale vermicomposting system and SOM data of the PMS (Appendix D), Greenhouse Gas Emission in Vermicomposting Drilosphere (Appendix E). Included in the presentation in Appendix D is the Vermicomposting process commonly practiced in organic farming in the Philippines, and a conceptual flow diagram of carbon movement in a vermicomposting bin drilosphere. A summary of the participants' views on vermitechnologies as platform discussion of climate change impacts and policy or technology support needs covered in the Consultation and Dialogue on Climate change at ISVT3 with the list of papers presented (Appendix F).

Linkages and Project Presentations

Linkages with several groups and institutions provided support to the APN Project. These included the local team at UPV comprised of the Chemical Engineering faculty and students, the local partners in the PMS, Southeast Asia Fisheries Development Center (SEAFDEC), National Institute for Marine Biology and Biotechnology(NIMMB), UPV Chemistry Department, UPLB-BIOTECH, Bureau of Plant Industry-Region 6, Soils Laboratory of STIARC-Region 4, PHILRICE, Office of the Provincial Agriculturist of Iloilo, and the Sugar Regulatory Administration Soils Laboratory. The participation of the senior Chemical Engineering students of the School of technology, UP Visayas opened interest on carbon, gas emission and climate change studies for student thesis research or special problems.

The APN LCI Project was presented in some national and local seminars and conferences such as at the Applied Biology Center for the Rice Environment (PHILRICE), in various seminars and trainings of the Agricultural Training Institute-6 of the Department of Agriculture, at the capability building seminar on green environment of the Philippine Normal University, Visayas, the national Bureau of Soils and Water Management, and at the 29th Research Forum of the School of Technology, UP. Visayas. Abstracts accepted for presentation were at the 15th Vemiculture Conference at Raleigh, North Carolina in July 2014, and at the International Conference on “Future Perfect: Cities at the Forefront of Change and Development” under the sub-area of Low-carbon development.

Manuscript for publication with the Journal of Natural Science of UP Visayas is undergoing revision. A manuscript sent to African Invertebrates Journal received advise for revision.

The Barriers

Project implementation during the first year met several impediments, nonetheless the Project was able to gather some basic information required to meet the project goals. Primarily, three very strong typhoons caused disruptions and damages in the monitoring sites and the need for resampling and re-setting-up. Over-flooding of the monitoring areas may have changed earthworm species density and population, as well as soil organic matter stabilization.

Among the issues and challenges were delays in obtaining sampling permits, transportation or handling certificates as required by government legislation, technical and methodological disagreements, difficulties in accessing the right equipment and facilities, higher cost of travel accommodations due to distant locations between monitoring sites.

The multi-disciplinary approach was effective and doable in this research, however cultural differences, norms and values, miscommunication and personal motives have significantly affected cohesiveness in project implementation. Orientation meetings and short visits failed to level out expectations.

Summary and Conclusion

A summary of the results give hopeful indication supporting the initial thesis that organic farming can help sequester atmospheric carbon in the soil and that the success and sustainability of this can be measured and monitored by sampling the abundance and biodiversity of resident earthworm populations, confirming the storage and transformation of soil organic carbon with application of organic inputs.

The gas emission data from binscale vermicomposting showed emission of gases during the pre-digestion of the wastes from 1- 15 days, regardless of the type of decomposing material. The low emission beyond 15 days when earthworms take a major role in the digestion and completion of wastes signified that earthworms did contribute to the greenhouse gas formation in the bins. The low emission of CO_2 and N_2O as the composting process progressed to completion (beyond 30 days) can be used as indicator of vermicompost maturity and stability, and its appropriateness for application in the field.

Higher density of earthworms were observed in the fields where food was available for them, such as in areas surrounding the poultry houses and in newly harvested sugarcane and corn fields. The earthworms in rice paddies were found along the drier parts of the field. In rice paddies, organic matter distribution was affected by the flow or movement of the floodwater and at water saturated conditions where earthworms were not found.

Long term application of vermicompost at PMS3 at the rate of 5-30 tons per hectare in more than 5 years seemed to have resulted to high organic matter build-up (and organic carbon storage) in the soils where different crops were grown. This build up was not observed in the rice paddies at PMS1 and PMS2 where organic matter application at the rate of 1.5 to 3.0 tons per hectare was practiced for 3-5 years.

No measurements of gas emission in the fields with high organic matter were done. Microbiological assay and carbon mineralization measurements were not completed.

Vermicomposting alone is already a source of N_2O and CO_2, but less of CH_4. The desired anaerobic condition in vermicomposting technology is now fully achieved, rather a facultative anaerobic condition is created that favors the generation of N_2O and CO_2. The presence of a large population of earthworms which are introduced at Day 15 did not contribute to an increase in CO_2 and N_2O generation. The main function of earthworms in vermicomposting is organic waste and organic matter stabilization and most probably, carbon fixation. Likewise, vermicompost application in the long term can increase organic matter content of the soil and introduce *E. euginate* back into the soil through the inclusion of cocoons in the vermicast or vermicompost.

The effect of the application of stable and mature vermicompost in organic farming is needed to create a macroview of C-footprint and an expanded view of a drilosphere.

Remaining activities will be continued in future with additional financial resources from other donors.

Appendix A

Timeline for Year 1

TIMELINE FOR YEAR 1 (2013-2014)

Project Activities	Apr'13	May'13	Jun'13	Jul'13	Aug'13	Sept'13	Oct'13	Nov'13	Dec'13	Jan'14	FEb'14	Mar'14
Preliminary Activities: preparation of documents, evaluation and selection of study sites	🟦											
Inception meeting with project partners and local cooperators		🟦										
Model development, methodology standardization and refinement, permanent plot set up		🟦	🟦	🟦	🟦	🟦	🟦					
Data collection		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Data analysis		🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	🟦	
Field observation of foreign participants in Philippines							🟦					
Technology transfer and establishment of permanent plots in Vietnam								🟦				
Review and refinement										🟦		
Drafting, finalization and submission of Year 1 Report										🟦	🟦	
Midterm Review, Project Planning for Year 2 and Inception Workshop												🟦

Events	Data /Venue	Estimated no. of Participants
1. Project Inception and Planning Workshop	May '13	Foreign Participants - 2
	Philippines	Local Participants - 10
2. Field observation in the Philippines	October '13	Foreign Participants: 5
	Philippines	Local Participants - 2
3. Training on vermitechnology and establishment of beds; Consultation	November'13	Foreign Participant - 3
Dialogue with Policy Makers and Practitioners during ISVT 3	Vietnam	Local Participants - 15
4. Midterm Review, Project Planning for Year 2 and Inception Workshop	March'14	Foreign Participants-5
	Vietnam	Local Participants-10

APPENDIX B

PERMANENT MONITORING SITES (PMS)

Permanent Monitoring Site 1- Kahariam Farms, Inc. (KFI)

KAHARIAM Farms in Lipa City, Batangas is an integrated organic farm with the biggest earthworm farming activity in the Philippines with a production capacity of 3 tons vermicast day-1, and a composting earthworm population of about 18-21 tons from a vermicomposting production area of more than a hectare. During the last decade, KFI increased land area and operations from the original 2.5- hectare horse farm into a 23 -hectare integrated organic farm that produces certified rice and rice seeds and caters to the demand of the organic rice industry in the Philippines and all of Southeast Asia. Integrated into organic farming production are free-range chicken and eggs, ornamental plants and vegetables. Plant and animals wastes are processed through vermicomposting that produces certified organic vermicast used in its rice and vegetable production or sold. Vermitea concoctions derived from brewing vermicast is used as foliar spray serving as nutrient sources and a bio-control for pests and diseases. Irrigation water is pumped from underground reservoir or adjacent river by wind mills.

PMS1 produces large bulk of African Nightcrawler (Eudrilus euginae, Kinberg 1867) which is the most widely used tropical composting species in the Philippines. In vermicomposting, horse manure and farm residues are mixed to serve as feedstocks to the worms. With its extensive vermicomposting operation, KAHARIAM is able to help several horse farms in the area to manage their animal wastes, and keep their soils and water sources free from possible contamination of pathogens from animal manure. Irrigation water comes from a controlled (underground and filtered) source. Inputs to organic rice production ranges from 1.5- 3.0 tons of vermicast per hectare and a weekly spraying of vermitea. Average rice yield is 90-120 cavans per hectare compared to average Philippine rice production (conventional lowland) of 70-90 cavans per hectare.

Permanent Monitoring Site 2- KFI Satellite Farm

PMS2 is a 10-hectare satellite farm of PMS1, located in Oton, Iloilo in Western Visayas. Production is devoted to organic rice and organic rice seeds. Like PMS1, the organic rice farming practices use farm-produced vermicompost, vermitea and biological pest control. The difference between the PMS1 and PMS2 is basically the number of years of practice in organic farming. As a satellite farm, PMS2 is under the conversion status from conventional to organic in three years. Within the site is an Elementary School that serves as the learning venue for organic vegetable and herbs gardening and vermicomposting. Unlike PMS1 which has no farming neighbors, PMS2 is surrounded by conventional rice farms that still practice the use of synthetic fertilizers and chemical-based pesticides. Source of irrigation water is the communal irrigation canal, in contrast to the deep-well irrigation water in PMS1. Inputs to organic rice production ranges from 1.5- 3.0 tons of vermicast per hectare and a weekly spraying of vermitea. Average rice yield is 70- 90 cavans per hectare lower than PMS1.

Permanent Monitoring Site 3- Peñalosa Farms

The Peñalosa Farms is a crop-livestock diversified organic farm located in the northern Negros Occidental. It is one of the pioneering organic farms in Negros Island, the organic island of the Philippines. PMS3 has developed its strength in probiotics research, which may be considered as vermitechnology-based because of the use of vermicast as as base for probiotic concoctions. Peñalosa farms is known for its innovations in organic farming technologies using earthworm casts as the base material in the production of enzyme-enriched fertilizing materials. Recent innovations in organic fertilization practices include direct field application of mill ash and mudpress on sugarcane, rice and vegetables. Vermicomposting is also carried-out directly under poultry houses and beneath pigpens with the concept that worms will move to where food is available. Hence there is no need to contain them in vermi-beds or vermicomposting windrows. It might be that Peñalosa Farms has an organic farming system whose contribution to carbon sequestration and greenhouse gas emissions is different from the other sites because of emphasis on microbial enrichment of its vermicast-based preparations.

Figure B.1 Location of the three Permanent Monitoring Sites

Appendix C

Information on Earthworms

The function of earthworms in soil carbon sequestration was observed in a laboratory experiment (Martin, 1991). The carbon mineralized from incubated worm feces or “casts” was almost 3.7 times less (at 3% per year) than that from non-ingested soil (at 11% per year). The carbon-protection factor was attributed to the compact structure of the casts produced by *Millsonia anomala* species under laboratory conditions. However, the observations was not confirmed completely in subsequent field experiments. Barois and Lavelle (1986), emphasized that much of the nutrients were obtained from earthworm excretion of urine and secretion of mucus, which also protects the Organic Matter (OM) from mineralization. Lavelle (1997) expressed the effects of earthworms on Soil Organic Matter (SOM) at different spatial and temporal scales. At larger-scale domains (soil profile to ecosystem), earthworms seem to accelerate the mineralization and the turnover of SOM, and attention on other function of other ecological groups of earthworms was emphasized (Villenave et al., 1999). The OM-protection function of the cast is a factor that needs to be investigated within the context of carbon sequestration or fixation.

Although the favorable role of earthworms in carbon sequestration in the soils is well documented, new findings by a group of researchers from different countries have created an “earthworm dilemma” (Pidcock, 2013). By combining all results of several studies relating to earthworm function in the soil, it was found that the presence of earthworms in soil increased nitrous oxide emissions by 42 per cent and carbon dioxide emissions by 33 per cent (Lubber et al, 2013). The transformation of fresh litter to CO_2 and NO_2 occurs when these are digested in the earthworm gut together with the soil mineral particles as the earthworm takes its normal movement of ingestion of soil particles and organic matter while burrowing (Fig. C-1).

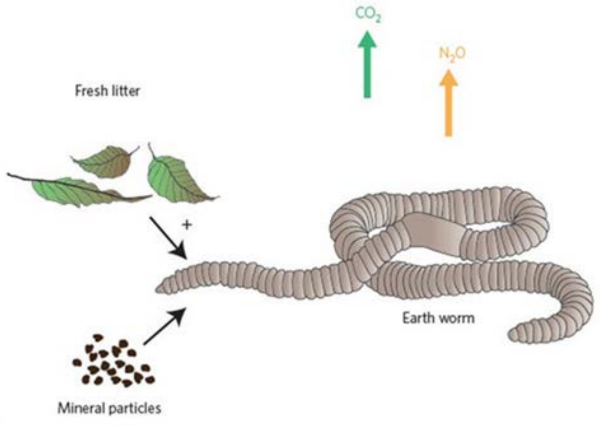


Figure C-1. Earthworms increase carbon dioxide and nitrous oxide emissions from soil.
Adapted from Lubber et al. (2013)

The new finding suggest that although earthworms are largely beneficial to soil fertility, they increase net soil greenhouse-gas emissions, therefore earthworms play an essential part in determining the greenhouse-gas balance of soils worldwide. The APN-LCI research, among its objectives, intended to observe the relationship of earthworm species and abundance to the emission of CO2 and NO2 under cultured condition such as in bin vermicomposting, and in fields that have been applied with organic matter in the form of vermicompost or vermicast during the last five years or more.

Earthworm Species.

Earthworm sampling in the organically maintained fields and from vermicomposting facilities for species ID and estimation of their abundance were major works in Year 1. The process of earthworm sampling, processing and analysis was exploratory at the start because no written procedures were available. The experience and errors encountered largely contributed to the development of a manual on "*Method on Earthworm Sampling, Identification and Estimation of Field Abundance"* that can be useful to future works. The protocol includes the process of sending biological samples abroad for analysis, noting that research relating to earthworms is very few in the Philippines. In is noted that the Department of Agriculture does not include earthworms under "Livestock". Rather, the permit for earthworm samples was obtained from the Quarantine Section of the Bureau of the Plant Industry.

The earthworms identified from the three sites and adjacent fields are listed in Table C-1. For species ID, two methods were used, i.e. based on structural characteristics observed under a microscope (Method 1), and DNA sequencing through BLAST (Method 2). By physiological examination), approximately seventeen species were identified from the different locations at PMSI, and only 6 different species were identified by BLAST. Four species (*Eudrilus, Megascolecidae, Metaphire bahli, Amynthas sp.)* were commonly identified under both methods. Enchytraid worms plus leeches were excluded. With both methods, *Eudrilus euginae,* Kimberg 1867*)* was the most prevalent epigeic type common in all vermicomposting sites. This conforms to the fact that *E. euginae* is the widely used species in vermicomposting in the Philippines. The species found in PMS2 and PMS3 were common taxa with earthworms in PMS1. Quadrat sampling was used to estimate abundance on a per hectare basis.

Table C-1. Physiological identification of earthworms collected from the Permanent Monitoring Sites (PMS). (Collection dates: March, May and November 2013 and February 2014).

PMS1	PMS2	PMS3
Pheretima cf. callosa *Amynthas sp.* *Drawida cf. barwelli* *Drawida sp.* *Eudrilus euginae* *Perionyx excavatus* *Eukerria saltensis* *Megascolecidae* *Dichogaster modigliani* *Dichogaster saliens** *Dichogaster cf. annae* *Pleionogaster cf. horsti** *Metaphire bahli* *Metaphire sp. nov.** *Polypheretima elongata* *Metaphire houlleti* *Eukerria saltensis* *Enchytraeus sp.* Conventional Fields *Drawida sp.* *Polypheretima elongata* *Amynthas sp.*	*Eudrilus euginae* *Polypheretima elongata*	*Eudrilus euginae* *Metaphire peguana* *Metaphire bahli* *Drawida sp1.* *Drawida sp.* *Eukerria saltensis* *Polypheretima elongata* *Amynthas sp.* *Enchytraeus sp.* *Natives:* ***Adudulay* ***Lago*

* May be new species for the Philippines (Blakemore, personal commumnication 2013).

** Local terms for native earthworms in the Philippines (DNA not yet known).

Species positively identified were composed of natives and exotics; two natives are considered species new to science and one exotic is a new record for Philippines. Interestingly, the closest match of supposedly cosmopolitan species, *Metaphire bahli* (Gates), was from Vietnam where the PhD candidate working on these identifications was contacted by the Korean partner for future collaboration.

At PMS 2, only one species, *Polypheretima elongata,* was found under rice which, although also present in adjacent non-organic fields, was possibly slightly higher in population i.e. approximately 5 versus 2.6 earthworms m^{-2}. These data are merely indicative. Also of note was that while the non-organic rice paddies had high infestation of golden apple snail and black rice bug, these were not prevalent in the organic farm. During the conversion period from conventional to organic, increase in paddy rice yield from the 60 cavans to 90 cavans Ha^{-1} was noted (PMS2 farm record, 2012 and 2013). The organic rice yields in PMS2 was substantially higher than the adjacent conventional farms.

Table C-2. BLAST results on earthworms collected at PMS1. (May and November 2013).

Species identification	
Eudrilus eugeniae	100%
Eudrilus eugeniae	100%
Eudrilus eugeniae	82%
Megascolecidae sp.	85 %
Megascolecidae sp.	86%
Metaphire bahli	99%
Metaphire bahli	99%
Metaphire bahli	99%
Amynthas sp.	86%
Amynthas sp.	86%
Amynthas sp.	87%
*Acanthodrilidae****	87%
Hormogaster huescana	82%

At PMS 3 organic fields, approximately 10-12 species of earthworms were identified by Method 1. Most of these were common taxa found at PMS1 except *Metaphire peguana* and *Metaphire bahli*. BLAST results in Table C.3 yielded only seven species in PMS3. All species except *Acanthodrilidae* sp. were also identified by Method 1.

To note are that PMS2 and PMS1 are on separate islands but with similar climate types. By the Corona system, PMS1 and PMS3 belong to Climate Type 3, while PMS 2 belongs to Climate Type 1 (PIDS, 2005). The survey locations on PMS3 were at the home farm compost facility, rice paddies, sugar cane fields at different crop growth stages, vegetable beds, banana and coconut plantations as well as unfarmed and more natural sites.

Table C-3. Blast results on earthworms collected from the PMS3 (January 2014).

Species	
Eudrilus euginae	100%
Amynthas sp.	87%
Metaphire bahli	99%
Amynthas lini	86%
Acanthodrilidae sp.	82%
Acanthodrilidae sp.	82%
Hormogaster huescana	82%
Megascolecidae sp.	84%
Megascolecidae sp.	85%
Megascolecidae sp.	88%
Amynthas sp.	87 %

The earthworm collections were intended for deposition at the National Museum but, while this was found not possible, the vouchers are being stored at the National Institute of Molecular Biology & Biotechnology (NIMBB) Laboratory of the University of the Philippines Visayas.

Abundance

Eudrilus eugeniae – also known as the African Nightcrawler (ANC) was the confirmed composting species was at all three organic sites. The ANC were introduced to vermicomposting units at the rate of 1 kg (approx. 1,200 worms) per 0.15 cu.m. Average of 5 samples were randomly collected from all vermicomposting beds for the purposes of species identification. Estimation of abundance for all beds was not included. A manuscript was submitted to the journal AFRICAN INVERTEBRATES updating its taxonomy, ecology, distribution and newly reporting its DNA profile for rapid identification of ecotypes/strains in the future.

During the peak dry period in 2013, the highest abundance at PMS1 was 183 earthworms m^{-2} with a biomass of 239 kg ha^{-1} or 0.24 t ha^{-1} in an adjacent to the poultry house (Tables C.4). This population is equivalent to 1.8 million field worms ha^{-1}, while the total population of vermicomposting specimens was estimated as 18-21 million worms in all the vermicomposting worm beds at PMS1. At the start of the wet period (April 2014) highest abundance of field worms was 128 earthworms m^{-2} or a biomass of 167 kg ha^{-1} or 0.18 ton ha^{-1} equivalent to approximately 1.6 million field worms per hectare.

Organic rice field in PMS1 had approximately 36 earthworms m^{-2} while adjacent conventional rice fields at equivalent crop cycle had approximately 23 earthworms m^{-2}. Biomass and species compositions data are not completely worked out for PMS1. In terms of earthworm biomass and population, the organic rice field is higher compared to the adjacent conventional rice field. Food availability to the worms seems to be the main factor for the highest population in the field adjacent to the poultry house with an average of 156 worms m^{-2} (Table C.4). More worms were found in the organic rice field with an average of 33 worms m^{-2} than in the conventional rice field with an average of 17 worms m^{-2}.

Table C-4. Number of earthworms (m^{-2}) collected from locations at PMS1 (May 2013

Sampling Point	**Vegetable field**		**Field adjacent to poultry area**		**Organic rice field**		**Conventional rice field**		**Vermicomposting beds**	
	May	Apr	May	Apr	May	Apr	May	Apr	May	Apr
1	0	2	35	25	2	1	2	2		
2	0	2	51	11	1	2	0	1		
3	3	3	14	24	7	2	0	2		
4	6	4	6	6	5	6	3	0		
5	7	1	47	27	5	4	0	0		
6	0	2	6	2	6	3	3	0		
7	2	2	0	5	3	0	8	2		
8	0	3	9	1	1	2	2	2		
9	0	1	15	15	0	2	4	1		
10	0	1	0	12	6	8	1	1		
Total number	18	21	183	128	36	30	23	11		
Average	20		156		33		17		5*	5*

*Average number of random samples taken from all vermicomposting beds.

Higher abundance of earthworms was found in the organic than conventional fields at PMS3 (Table C.6). Among the organic fields, the newly harvested cane field had highest number of earthworms with 99 earthworms m^{-2} compared to adjacent conventional farmed fields with 11-29 earthworms m^{-2}.

At PMS2, abundance and biomass of earthworms inside the school garden that was applied with vermicompost in the last 5 years was significantly higher than areas outside the school premises, the non-organic or conventional field and the conversion rice field (3-year organic). At PMS3, earthworm abundance was highest in the newly harvested can field among the sampling areas. To note is that the cane trashes where not yet removed at the time of sampling.

Table C-5. Number of earthworms (m^{-2}) and average biomass (g) collected from PMS2

Earthworm	Inside School	Outside School	Conventional Field	Conversion Fields
Number	24	6	7	5
Average weight (g worm^{-1})	0.081	0.055	0.010	0.049

Table C-6. Earthworm population (m^{-1}) at PMS3.

Field Type	Organic	Non-Organic
Ricefield	24	-
Harvested canefield	99	-
Replanted canefield	17	29
Mature canefield	17	11
Banana field	15	-
Vegetable field	7	-

Appendix D

Soil Organic Matter/ Organic Carbon and Microbiology

Organic Matter Transformation in Vermicomposting

Assessment of the carbon content of the soils and compost were done through chemical analysis. The low-carbon research works on the premise that carbon sequestration from increasing soil organic matter (SOM) is directly proportional to a net reduction in greenhouse gases (Drinkwater et al 1998, Mader et al 2002, Pimentel 2005, Reganold et al 2001).

Information about vermicomposting systems and the farmers' practices were obtained from farmers and practitioners through a random survey, and interview of participants during the ISVT3 in November 2014. The common vermicomposting process is illustrated in Fig. D.1. Vermicomposting starts with the particle-size reduction of biodegradable solid wastes(by manual or mechanical shredding). The shredded materials are thenmoistened to about 60-70 % moisture and subjected to pre-digestion at anaerobic condition. However, based on the researcher's observations, the anaerobic condition may not be fully met in larger vermicomposting beds which do not exclude oxygen. In most set-ups, maximum temperature range of 50-55°C was read. Although this temperature range is within thermophilic, not enough heating may not be able to destroy the pathogens in the animal manure which is co-digested with food and other cellulosic farm wastes like leaves and grasses. Carbon-to-nitrogen ratio ranging 20:1 to 30:1 is assumed being met by the 3:1 cellulose-to-manure mixtures commonly followed as a rule of thumb. As a composting technology, the mesophilic (<40°C) and thermophilic(40°- 70°C) stages are important in the co-digestion of waste into a stable humus-like material. Thermophilic phase is necessary to kill weed seeds and pathogenic organisms to prevent contamination of the mature vermicompost and possible transfer into the soil and food crops.

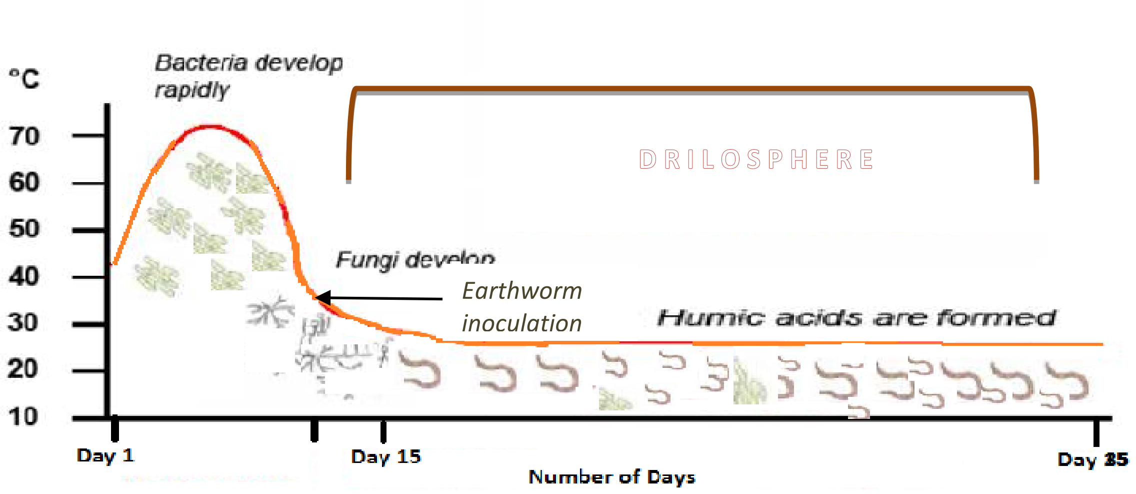


Figure D.1 . Flow diagram of organic matter transformation in vermicomposting

Emission of methane and nitrous oxide can occur because of the breakdown of proteins, carbohydrates, lipids and other components of wastes during the anaerobic digestion which occurs actively within 7 -15 days from the start of composting. When the system does not provide full anaerobic condition, some anaerobic patches in the moist wastes may occur and this could provide a favourable condition for the generation CH_4 and NO_2. In contrast, CO_2 can be formed when oxygen supply is available during waste digestion. Maximum heat in vermicomposting beds occurred at 5-7 days (Figure D.1) after which temperature started to decline. At the cooling phase (10 to 12 days), fungi proliferate and actively continue decomposing the waste. ANC at the rate of 1.2 Kg 0.02 m^{-1} (approximately 1,200 individual breeders) is introduced after pre-digestion of waste, or at 15 days after the start of the process. The earthworm-compost/vermicast interaction creates a drilosphere. Drilosphere, according to Wikipedia (http://en.wikipedia.org/wiki/) is that part of the soil (or compost) influenced by earthworm secretions and castings. Specifically, it is the fraction of soil which has gone through the digestive tract of earthworms. The term "drilosphere" was coined by M. B. Bouche. Fig. D.2 illustrates. As a source of of CO_2, N_2O, and CH_4 , the gases evolved from the binscale vermicomposting were measured.

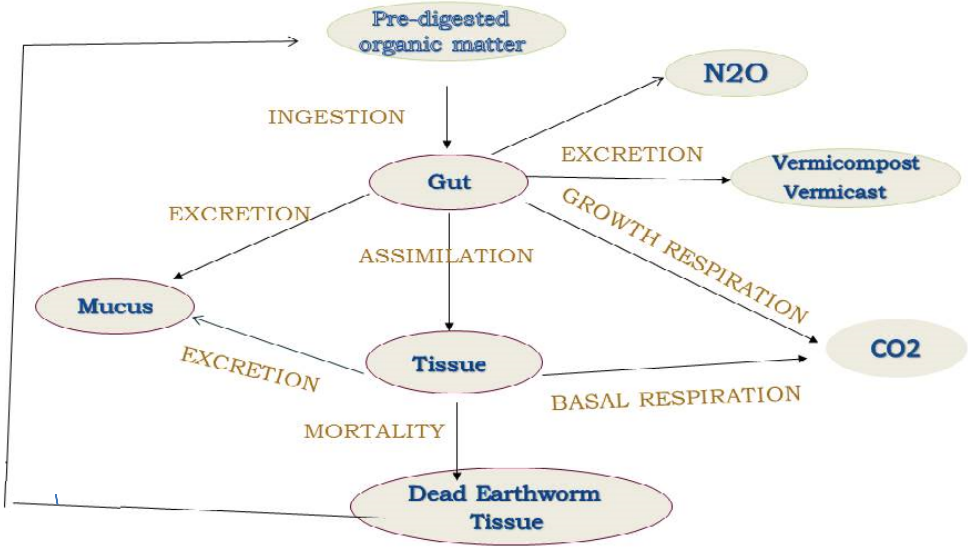


Figure D.2 . Organic matter transformation in a drilosphere (Modified from Ang Lopez , 2001)

5.52 Soil Organic Matter/ Soil Organic Carbon

Carbon occurs in the soils in both organic and inorganic forms. The greater part occurs in organic matter and in carbonate materials. Organic carbon occurs in all soils while inorganic forms occur in some soils. In humid conditions, the organic form of carbon dominates, while inorganic carbon is the form in dry conditions.

In organic farming where recycling of wastes into composts is highly promoted, organic carbon is the main form or soil carbon. In this research the organic carbon in both the soils and vermicompost were analysed by the Walkley Black Method (Black, 1965), a wet-digestion procedure wherein the oxidizable organic carbon in the soil or compost is oxidized with a dichromate and the quantity of the oxidized carbon is measured from the amount of dichromate reduced by a standard ferrous sulfate solution.

Year 1 provided benchmark data on the SOM and SOC, pH, moisture content and exchangeable capacity of the soils from the PMS. The soils in PMS1 that received vermicast at a rate of 1.5 to 3.0 tons per hectare has SOM content of 2.1-4.45% (Table D.1). The SOM among the organic rice fields and between organic and conventional rice fields did not differ significantly. A one- hectare, 15-in depth of soil in PMS1 has higher SOM than an average Philippines soils with 1.2-1.5 %OM content. The slightly higher level of SOM at PMS1 (Table D.1) seem to relate to the waste residues in the area at the time of sampling (e.g. poultry manure and corn waste residues) rather than coming from the applied vermicasts. The organic rice fields applied with 1.5-3.0 t Ha $^{-1}$ of vermicast per hectare per cropping season had 2.10 – 2.65 % OM. Theoretically, a fertile soil must have 5% OM.

At PMS1, high organic matter content around the poultry area have contributed to higher earthworm abundance. Poultry manure is known to be a good feedstock for vermiculture. Earthworm population in vegetable and rice paddy also differed significantly, but the lower population of earthworms in both areas compared with poultry area indicates lower availability of feedstocks and (organic matter) for earthworms. Regardless of soil moisture content and microbiological activity, the result seems to indicate that application of 3 tons of vermicompost per hectare in rice (0.30 Kg m^{-2}) and vegetables may not be enough to provide organic matter to attract more earthworms, or perhaps support the proliferation of earthworms.

Table D.1. Analysis of soils obtained from various locations at PMS1 in May 2013.

Identification	pH	% Organic Matter	% Organic Carbon	Moist Factor	EC (mm)
Field adjacent to Poultry area	5.50	4.55	0.633	14.00	0.320
Organic Cornfield, Newly harvested	5.59	3.17	0.441	14.29	0.290
Organic Rice field	6.17	2.65	0.541	12.36	0.331
Organic Rice field	6.10	2.10	0.406	15.61	0.249
Conventional Rice field	6.60	3.00	0.429	13.97	0.265
Conventional Rice field	6.69	3.37	0.441	18.06	0.218

SOM in the conventional rice field was higher than the organic rice fields. In the former, residual rice straw is left in the field and allowed to decompose under water saturated condition, then incorporated during land preparation.

At PMS2, SOM content of the soils in the range of 3.52-5.19 is higher compared to a typical Philippine soil with average OM content of 1.5 %. The garden lots inside the school showed very high OM of 5.19%. The school garden has practiced vermicomposting and organic farming for more than five years.

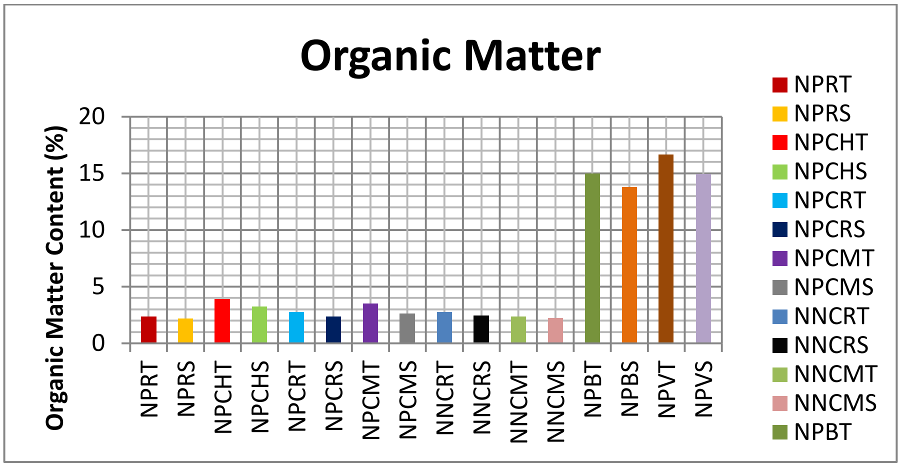
Table D.2. Analysis of soils from PMS 2.

Sample Source	pH	Organic Matter, %)
Organic conversion	5.6	4.03
Conventional field	6.0	3.52
Outside school	6.1	3.69
Inside school	5.4	5.19

Source: Sugar Regulatory Administration, March 2014

At PMS3, the SOM in the organic fields ranges 2.21-16.65% equivalent to 1.28 - 9.66% SOC (Table D. 3). The SOM of the conventional fields ranges from 2.24-2.73% or 1.30-1.58% OC. Based on the rate of application of 30 tons of organic matter per hectare in the form of mill ash, mudpress, carbonized rice hulls and vermicompost (Farm data

Table D.3. Organic matter content of soils from PMS 3.



2014, personal communication), the area potentially stores about 28.7 – 35.2 tons OC in a furrow depth. The soil organic matter content at PMS3 varied with the type of plant or crop. Vegetable and banana fields hold significantly higher OC than the rice and sugarcane soils. Direct field application of organic matter inputs seem to have effectively raised organic matter content of the soils which is ideal in soil fertility build-up. As long as factors contributing to carbon stability is present, the application of organic inputs can result to soil conditioning thatfavourable in crop nutrition. The pH level ranging 5.6 - 7.2 in organic fields is generally ideal for microbial activity supporting mineralization of nutrients. PMS3 demonstrates that adding organic matter can increase potential C-sequestration through SOC build-up. However, measurement of carbon transformation/mineralization is also necessary, and may be an additional activity in Year 2 of the Project.

The average sugar cane yield in northern Negros area, where PMS3 is located, ranges 60 – 90 tons Ha-1. The favourable effect of organic matter build-up must be valued not only on a crop yield basis, but also on other impacts like economics, and environmental health (climate change) and microbiological diversity in the soils.

At PMS3, the SOM in the organic fields at rangeds from 2.21-16.65% equivalent to 1.28 - 9.66% SOC (Table While the SOM of the conventional fields ranges from 2.24-2.73% or 1.30-1.58% OC. Based on the rate of application of 30 tons of organic matter per hectare in the form of mill ash, mudpress, carbonized rice hulls and vermicompost, the farm potentially stores about 28,767 – 35,234 Kg OC in a furrow depth. The soil organic matter content at PMS3 varied with the type of plant or crop. Vegetable and banana fields hold significantly higher OC than the rice and sugarcane soils. Direct field application of organic matter inputs seem to have effectively raised organic matter content of the soils which is ideal in soil fertility build-up. As long as factors contributing to carbon stability is present, the application of organic inputs can result to soil conditioning that favourablein crop nutrition. The pH level ranging 5.6 - 7.2 in organic fields is generally ideal for microbial activity supporting mineralization of nutrients. PMS3 demonstrates that adding organic matter can increase potential C - sequestration through SOC build-up. However, measurement of carbon transformation/mineralization is also necessary, and may be an additional activity in Year 2 of the Project.

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Some Data on Microbial Activity in Soils and Vermicompost

There is higher bacterial count than Molds and Fungi (Table D.3) in organic rice and organic corn fields at PMS1. In these fields, mold counts were also higher than Yeast count. Bacterial count of the vermicast was higher than all soils. Application of vermicompost at a rate of 3.0 tons hectare $^{-1}$ may have contributed to the increase of bacterial activity in the soils. Additional information on microbial activities including identification of the effective microorganisms in mineralization of SOC was not completed.

Table D.4. Bacteria, molds and fungal count of soils and compost from PMS1 and PMS2 sampled in May and July 2013.

Location		Purpose		
		Bacterial count (CFU/g)	Yeast Count (CFU/g)	Mold Count (CFU/g)
PMS 1. Organic Rice near gate	1	8.15 x10^{6}	<100	3.95 x10^{4}
PMS1 Organic Corn Field	2	1.04 x10^{7}	<100	4.45 x10^{4}
PMS1 Organic Rice	3	4.8 x10^{6}	<100	2.75 x10^{4}
PMS1 Conventional Rice	6	4.05 x10^{6}	<100	4.9 x10^{3}
PMS1 Conventional Rice Paddy	7	4.95 x10^{6}	<100	3.95 x10^{4}
PMS 2 Organic Rice	8	3.2 x10^{6}	<100	5.0 x10^{4}
PM2 Organic Rice	9	3.6 x10^{6}	<100	1.9 x10^{4}
PMS2 Conversion Fields	10	3.3 x10^{6}	<100	2.4 x10^{4}
PMS2 Conventional Fields	11	6.4 x10^{6}	<100	3.6 x10^{4}
PMS1 Vermicast	12	1.23 x10^{7}	<100	1.5 x10^{5}

Appendix E

Gas Emission Measurements

The most relevant anthropogenic sources of greenhouse gases such as CH_4, N_2O and CO_2 include agriculture and food waste. The agriculture sector is responsible for approximately 30% of all emissions from anthropogenic sources (Tubiello et al., 2013). Nearly half of all the GHG emissions from agriculture are accounted by the management of agricultural soils. In the United States, 15% of all GHG emissions from agriculture are accounted by manure management alone (Environmental Protection Agency [EPA], 2014).

Methane is known to be generated from continuously flooded fields such as paddy rice conditions especially loaded with organic wastes from plant and animal wastes. Cattle manure and fruit and vegetable wastes are commonly utilized as composting agents for quality composts used for agriculture (Risse and Faucette, 2012). Food wastes contribute a significant fraction to the total GHG human-made emissions. According to Venkat (2012), food waste accounts 2% of the total GHG emissions in the United States. Fruit, cereal and vegetable wastage is very common in Asia from which wastage of cereals, specifically rice, account for around 20% of the total anthropogenic emissions of methane (Food and Agriculture Organization [FAO], 2013). The Philippines produces large quantities of food waste everyday due to processing, distribution, and consumption (FAO, 2013). There is inadequate information about the quantities of actual emissions. It is necessary to conduct a GHG emissions inventory specifically for these types of sources since inadequate information of actual emissions from these wastes are available.

This research intends to provide an integrated assessment in the vermicomposting system where mineralization, volatilization and fixation of carbon from manure and food wastes take place. This study under the APN-LCI research project on carbon sequestration has three Phases, namely: Phase1- development of a gas measurement methodology, Phase2 – measurement of CO_2 and N_2O in the binscale vermicomposting drilosphere using the methods developed in Phase1, and Phase 3 - upscaling of gas emission measurement at the PMS facilities and fields and transfer of research to the stakeholders. Only Phases 1 and 2 were covered in Year 1.

Phase 1 - Development of Gas Collector and Method of Collection

This activity was participated by the Chemical Engineering faculty and students of the School of Technology, UP Visayas from September 2013 until March 2014 in line with the school's researches on waste management and climate change under its Environmental Technology research program. The study aimed to design a gas collector using local materials. Two sizes of gas collector were designed and tested for efficiency in co-digestion of cattle manure: plant waste, and food:wood wastes. These waste mixtures represent the common materials in vermicomposting by the organic farmers in the Philippines. Performance testing in terms of reliability, reproducibility, and accuracy were basis in the selection of the gas collector design. Six gases were included in performance testing namely O_2, CO, CO_2, NH_3, CH_4 and N_2O. The regression values of measurements from the two trials are presented in Tables E.1 and E.2. Of the two designs, Collector A (big, covered) was chosen. Collector A is illustrated in Fig. E.1.

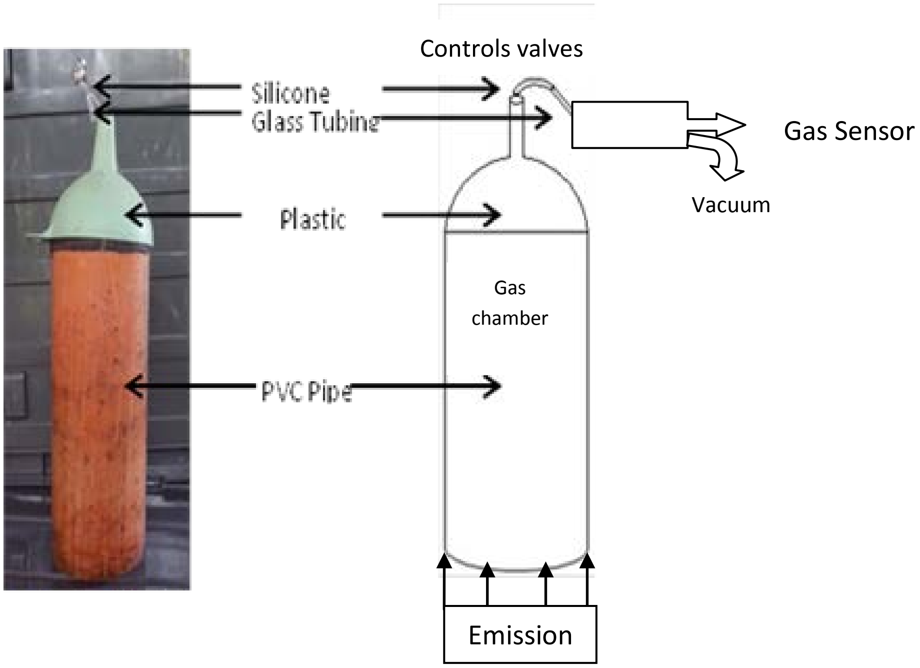


Figure. E.1 Design of the gas collector.

Table E.1 Regression values of gas generation from food:wood waste and cattle manure:plant waste from day1 to day 15 at 6th order polynomial.

Gases	R^2-values*	
	Food: Wood waste	Cattle Manure: Plant waste
O_2	0.66	0.81
CH_4	0.53	0.78
NH_3	0.88	0.89
CO	0.90	0.65
N_2O	0.73	0.88
CO_2	0.74	0.61

*R^2 - values are mean of 3 runs in 2014 D.S.

Table E.2 Regression values of gas generated from food:wood waste and cattle manure:plant waste after digestion at 6th order polynomial

Gases	*R^2-values	
	Food: Wood waste	Cattle Manure: Plant waste
O_2	0.66	0.68
CH_4	0.53	0.73
NH_3	0.88	0.74
CO	0.90	0.60
N_2O	0.74	0.61
CO_2	0.51	0.42

*R2 - values are mean of 3 runs in 2014 W.S.

Test for Anaerobicity

Oxygen concentration in terms of percent volume/volume (% v/v) was measured in the vermicomposting bins (Fig E.2) during the pre-digestion period of 15 days, in both composting substrates. As mostly practiced in the Philippines, the pre-digestion phase is 'claimed' anaerobic but no test has been done to determine the actual condition in different vermicomposting designs. Attainment of a thermophilic stage has always been emphasized as a necessary control for pathogen contamination of the compost or vermicast.

The results indicate that pre-digestion phase was not carried-out at full anaerobic condition. Rather, the condition in the bin was at a reduced oxygen level that may also favour generation of low level of CO2 from microbial activity, respiration and breakdown of proteins, carbohydrates, lipids and other components of the wastes. Slight differences in O_2 was observed between the two substrates and from the two types of collectors. Collector B yielded more O_2 (Figs. E.4 and E.6) than Collector A (Figs. E.3 and E.5) in both types of waste mixtures. O_2 gas by Collector B was 15-16% (v/v) from Cattle Manure:Plant waste and 4.0 to 13% (v/v) from Food:Wood waste. While 10 to 15% (v/v) and 1.7 to 8.8% (v/v) for Cattle Manure:Plant waste and Food:Wood waste, respectively were observed with Collector A. In summary, with the two collectors and two types of decomposing waste mixtures, O_2 in the bins ranged from 1.7% to 16% (v/v). The oxygen gas in the vermicomposting system was lower than 21% (v/v).

Figure E.2. Installed gas collector.

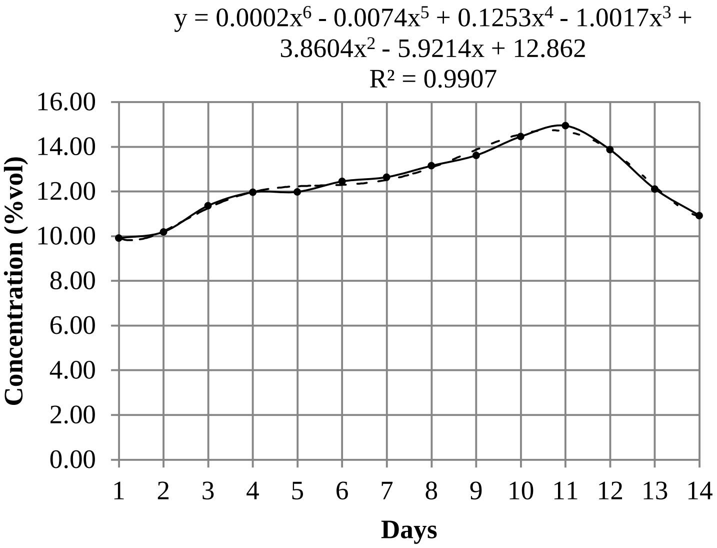


Figure E.3. Minimum amount of oxygen (O_2) generated from Cattle Manure:Plant waste from 1st to 14th day of digestion using Collector A.

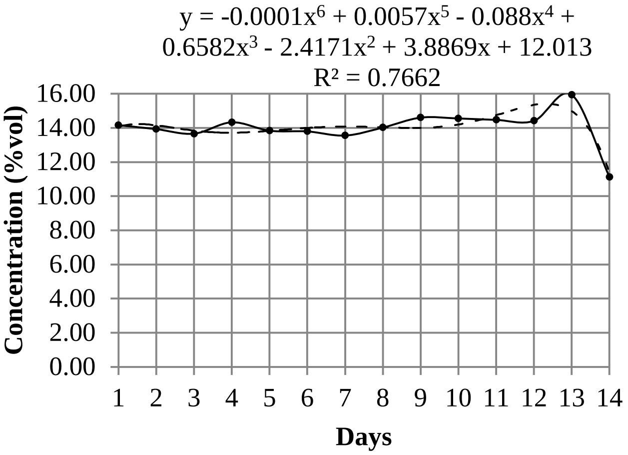


Figure E.4. Minimum amount of oxygen (O_2) generated from Cattle Manure:Plant waste from 1st to 14th day of digestion using Collector B.

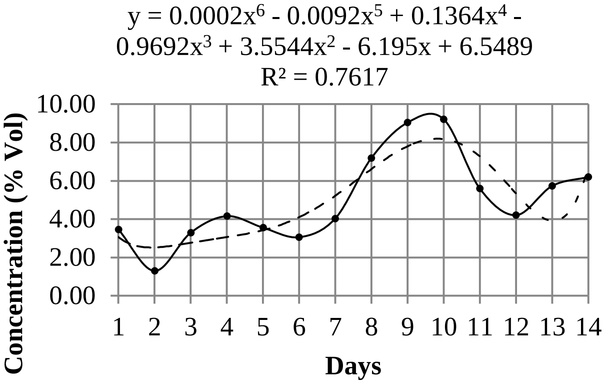


Figure E.5 Minimum amount of oxygen (O2) generated from Food:Wood waste from 1st to 14th day of digestion using Collector A.

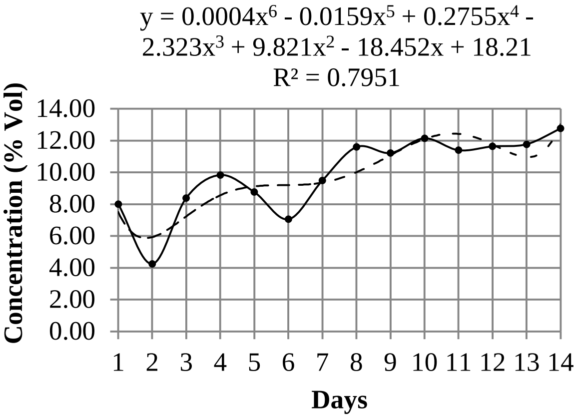


Figure E.6. Minimum amount of oxygen (O_2) generated from Food:Wood waste from 1st to 14th day of digestion using Collector B.

Phase 2 - CO_2 and N_2O collection and sensing in binscale vermicomposting

The principal factors affecting GHG emission from waste are the amount of waste and portion that decomposes anaerobically. The type of waste and temperature are the primary factors that determine the extent of anaerobic decomposition that takes place. For instance, the amount of N_2O released depends on the system and duration of waste management. Because N_2O production requires an initial aerobic reaction and then an anaerobic process, it is theorized that dry, aerobic management systems may provide an environment more conducive for N_2O production. With a claim that vermicomposting drilosphere is a point source of CO_2 and N_2O (Fig. D.2), Phase 2 was carried-out in a binscale measurement of the two gases following a randomized complete block design in two runs, with replications per run. The runs were done in 3 periods, namely Run 1- Dry Season 2014, Run 2- Wet Season 2014.

Set-Up of the Vermicomposting Drilosphere

Plastic bins with dimensions 57cm x 45 cm x 33.5 cm (L x W x H) were used for composting two substrates: (1) 5:1 mixture of cattle manure and plant waste, and (2) 5:1 mixture of food and wood wastes.

Cattle manure and plant waste were collected from the vicinity of UPV, Miag-ao, Iloilo. Plant waste was composed of leaves, cut grass, and weeds. This plant waste was sun dried for two days to reduce the moisture content and stored in garbage bags. Plant waste was used as a bulking agent for cattle manure. Prior to mixing, cattle manure was reduced to smaller sizes. The mixture was prepared in a plastic bin containing 10 kg of cattle manure and 2 kg of yard waste, creating a 5:1 ratio of organic mixture. After mixing, 18 kg of water was added in the container so that a moisture content of approximately 60% was prepared for the setup. Sawdust was used as the bulking agent for the food-wood waste mixture. The ratio of the mixture was the same as that of the cattle manure-plant waste mixture. The mixture consisted of 22.5 kg of food waste and 4.5 kg of sawdust. The composting process was done in a dry, shady space within the UPV Site Development Reforestation Project in Miag-ao, Iloilo.

For RUN 1 and 2 gas collection and measurement was carried-out every six hours (0-6-12-18 hours) for the first 15 days of composting and another 15 days after the addition of earthworms into the bins. For run 3, one month predigestion was carried-out, one- week rest, then addition of earthworms 30 days after.

The regression values (Table E.3) proves reliability of the measurements in Phase 2. At reduced oxygen condition in the bins, CH_4 generation was not completely ruled-out because of the presence of compressed and exudate-saturated packets within the decomposing substrates. However, low generation, (<1.0 ppm CH4) led to the exclusion of CH_4 measurement and leaving CO_2 and N_2O as the main focus in the study. Carbon dioxide comes from the biological (e.g. microorganisms and earthworm respirations) and organic matter digestion, while N_2O can be generated from the reduced conditions within the anaerobic patches and from the guts of earthworms.

The collected gases were initially read by gas chromatography, however, to avoid error due to transport and handling of samples from the collection site to the laboratory, a calibrated gas sensor (GASTECH PHD6) was used for the measurement.

Table E. 3. Regression values of N_2O and CO_2 emitted from food:wood waste and cattle manure:plant waste.

Gas	Period of measurement	Mean r^2-values of food:wood waste	Mean r^2-values of cattle manure: plant waste
N_2O	0-15 days	0.73	0.88
	16-45 days	0.74	0.78
CO_2	0-15 days	0.74	0.78
	16-45 days	0.51	0.42

Amount of N_2O and CO_2 Generated from Food:Wood Waste Mixture

Food:wood waste mixture generated more gases during the pre-digestion phase and beyond. Indicative is that the first 15 days is a critical period in terms of gas generation, thus must be managed properly to minimize GHG emission. In cattle manure:plant waste mixture, beyond 15 days showed compost stability and maturity because CO_2 was generated minimally, (Figs E.6-Fig E.11). Using the Model equation, the computed amount of gas emitted from each decomposing substrate shows higher generation of gases from the food:wood waste mixture compared to cattle manure:plant waste. The presence of earthworms beyond 15 days seem to have no influence on CO_2 and NO_2 generation. African nightcrawler was introduced into the composting bins right after the pre-digestion phase, or at the 16th day when the system was made fully aerobic.

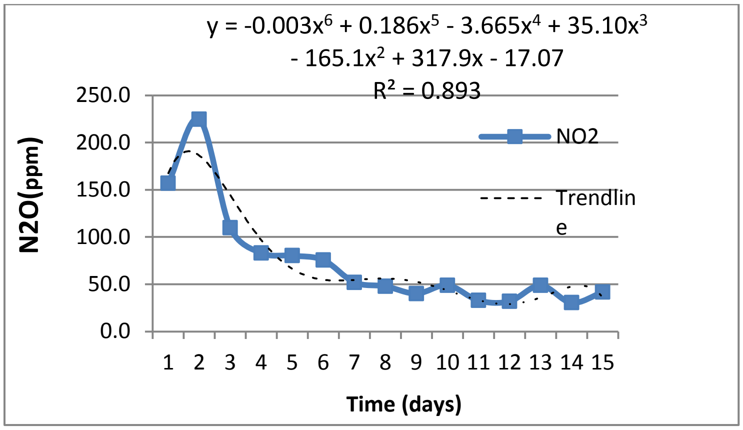


Figure E.7. N_2O generated (ppm) in Run 1, Food:Wood waste substrate from 1-15 days.

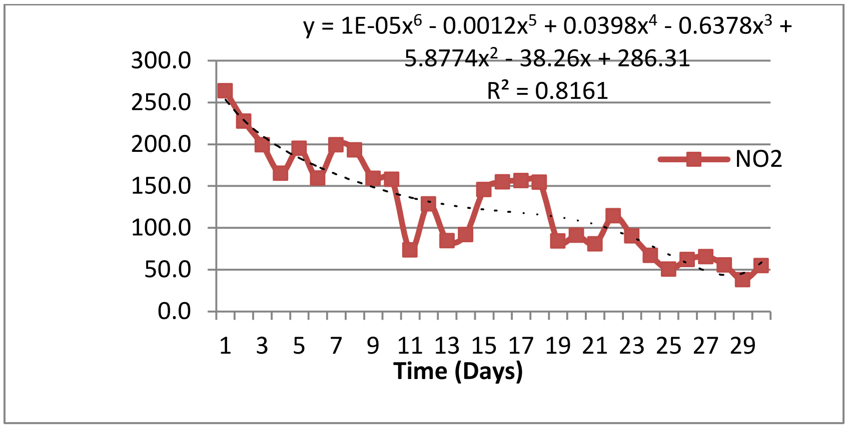


Figure E. N_2O generated (ppm) in Run 2, from Food-Wood waste mixture from 1-35 days in binscale vermicomposting

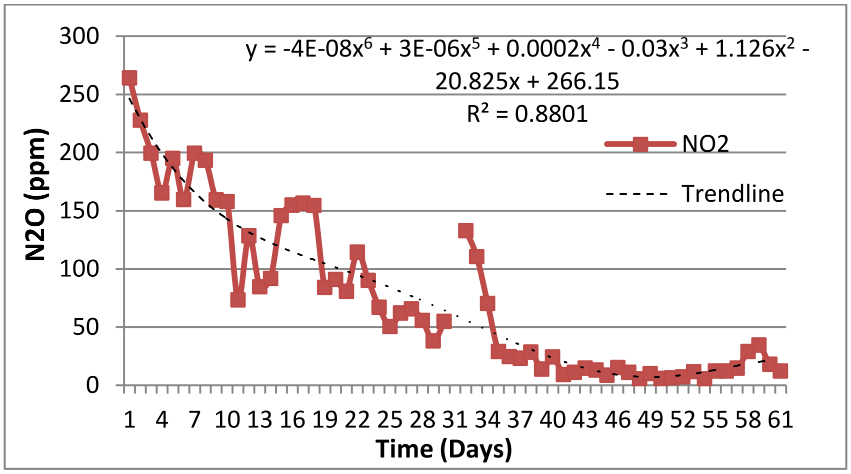


Figure E.9 N_2O generated (ppm) in Run 3 of Food:Wood waste mixture in binscale vermicomposting. Measurement was extended to 65 days

CO_2 EMISSION

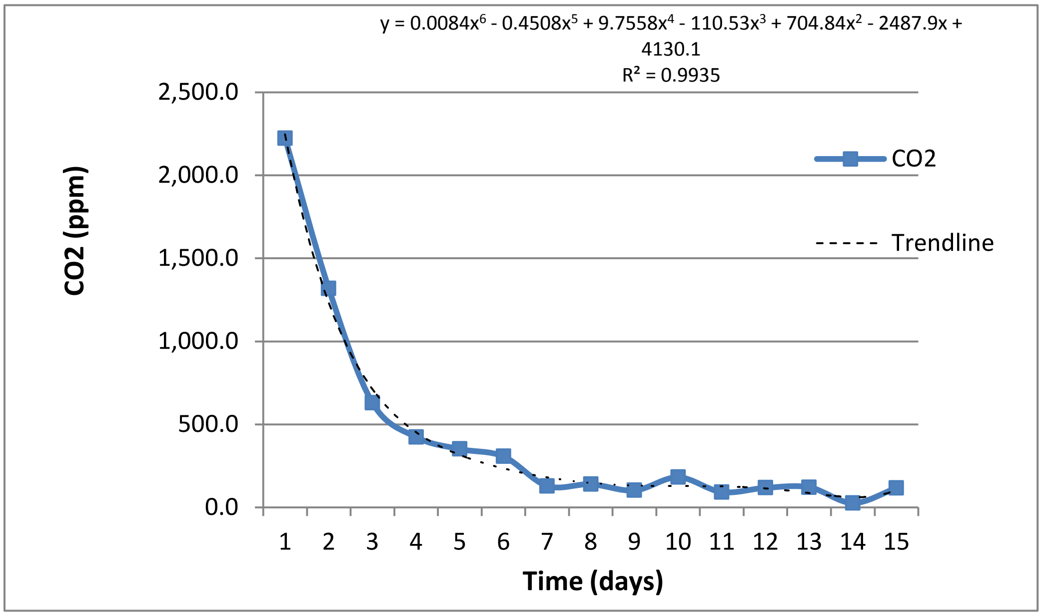


Figure E.10 CO_2 generated (ppm) in Run 1, Food:Wood waste mixture from 1-15 days in binscale vermicomposting.

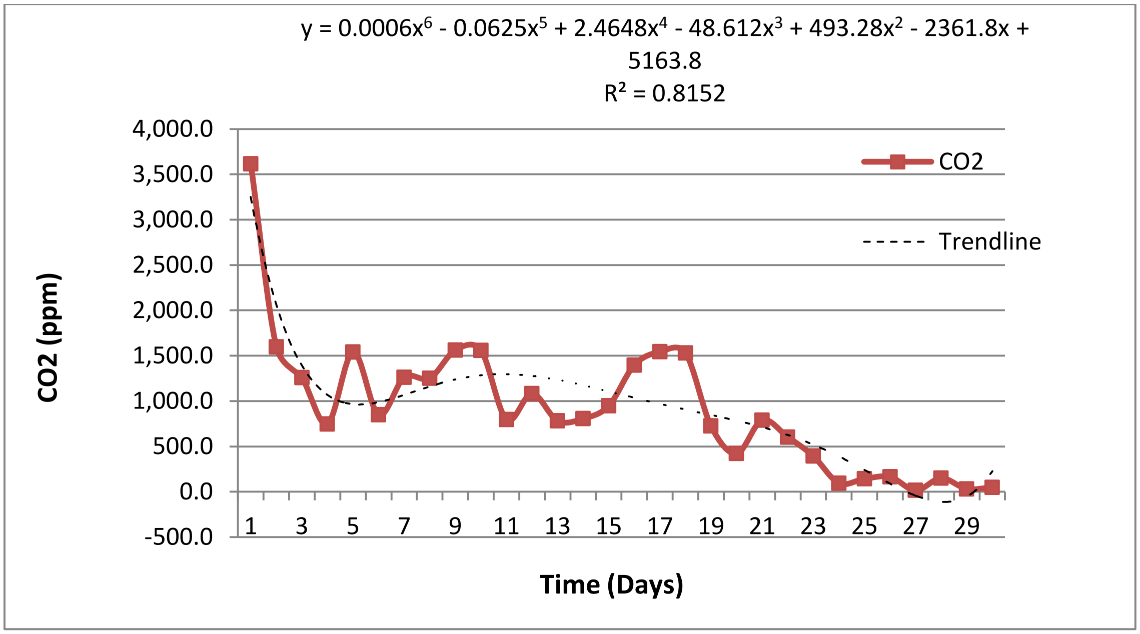


Figure E.11 CO_2 generated (ppm) from Run 2, Food:Wood waste substrate from 1-35 days in binscale vermicomposting.

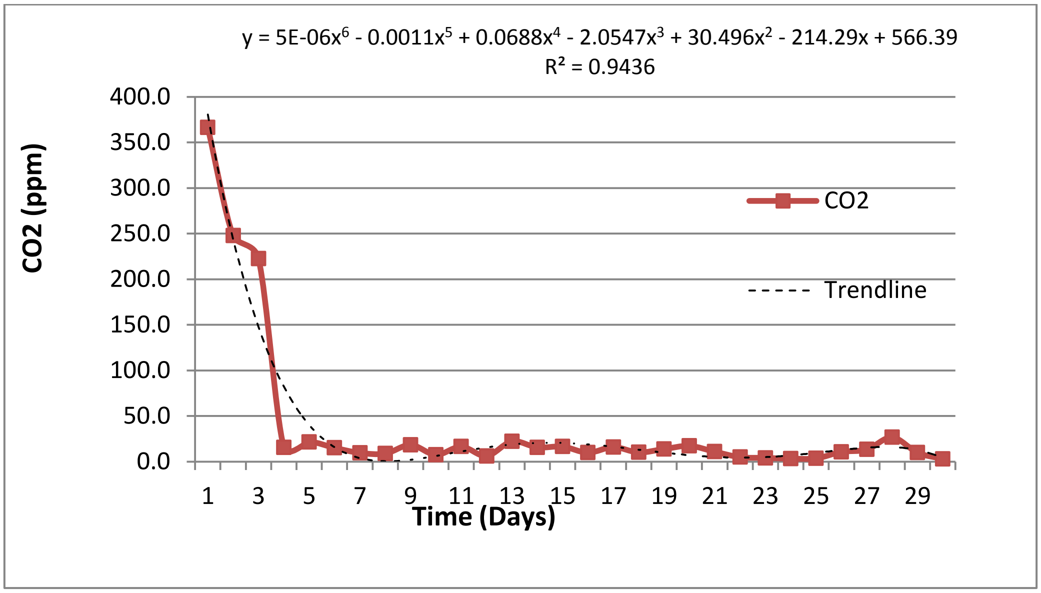


Figure E.12 CO2 generated (ppm) in Run 3 Food:Wood waste mixture from 1-35 days in binscale vermicomposting.

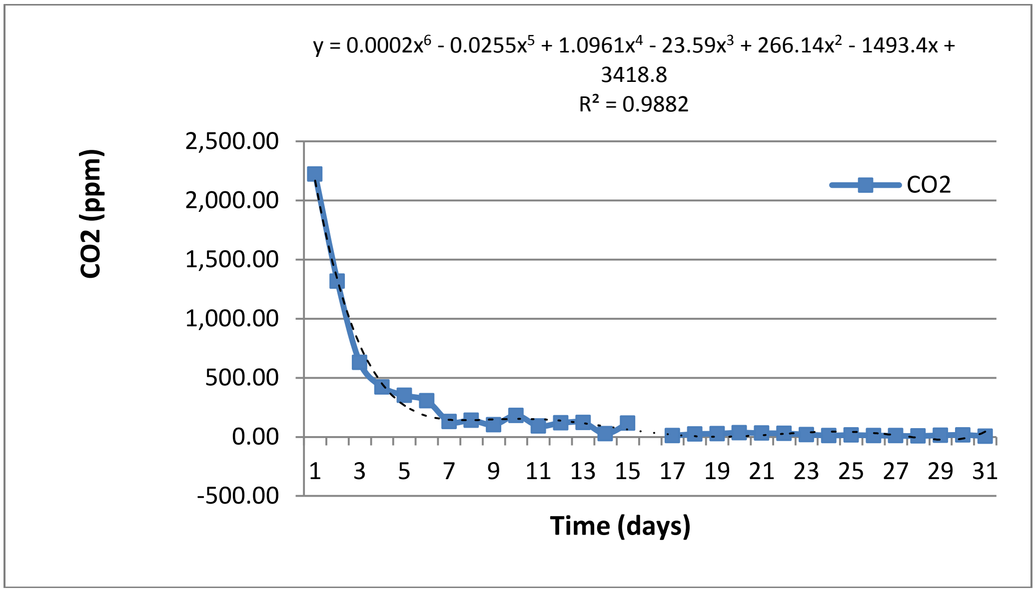
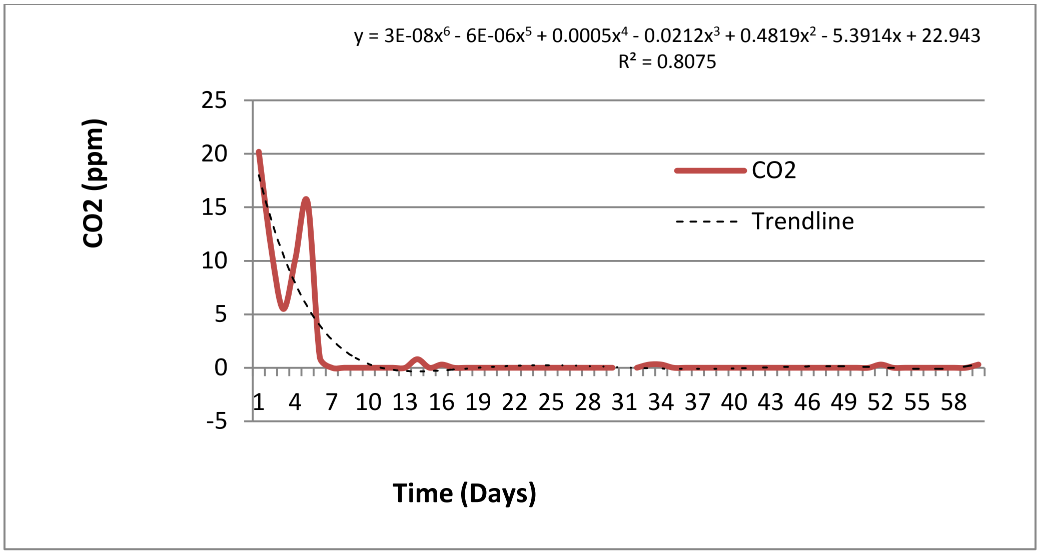


Figure E.13. CO_2 generated (ppm) in Run3 of Food:Wood waste substrate from 1-35 days in binscale vermicomposting.



Methane

Figure E.14. CO_2 generated (ppm) in Run 4 from Food:Wood waste mixture from 1 to 65 days in binscale vermicomposting.

Test for Methane

At reduced oxygen condition in the bins, CH4 generation was not completely ruled-out because of the presence of compressed and exudate-saturated packets within the decomposing substrates.

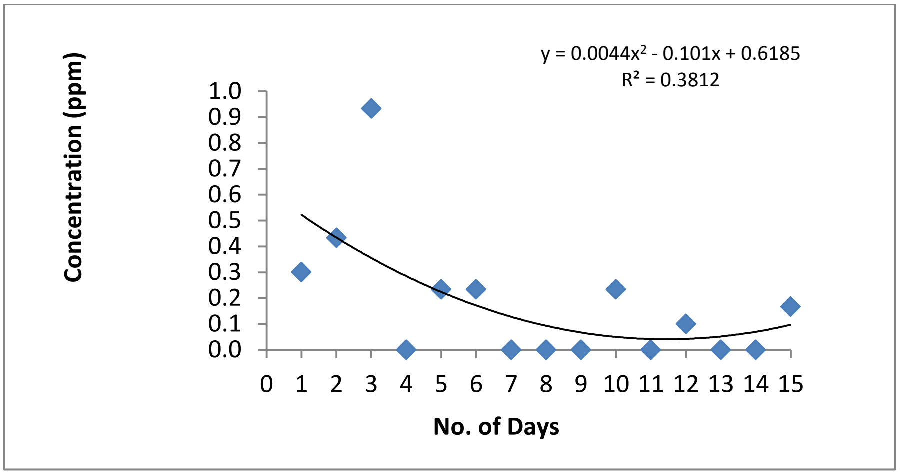


Figure E. 15. Methane gas generated (ppm) from Decomposing Cattle Manure:Plant during pre-digestion phase.

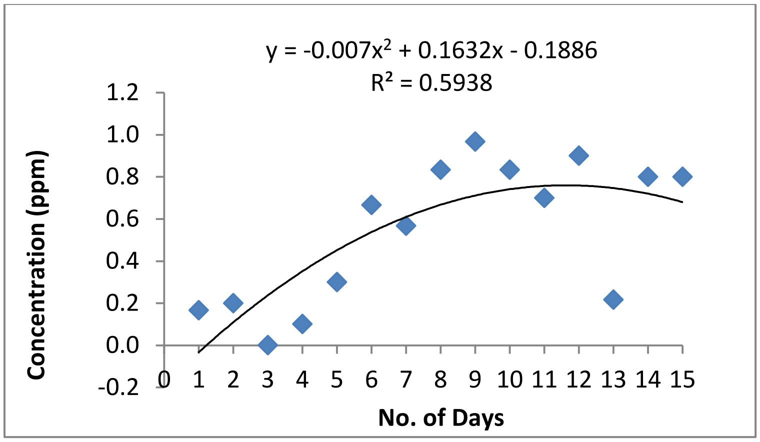


Figure E.16. Methane generated (ppm) from decomposing Food:Wood waste from 1-15 days.

The NO_2 and CO_2 were generated from a decomposing food:wood waste and cattle manure:plant waste mixtures that have undergone decomposition and stabilization for 45-50 days accompanied by a mass reduction of 65% (volume basis). From a carbon to nitrogen ratio of 30:1, the stabilized mass (vermicompost) were analysed for organic matter content as shown in Table E.4. Mineralization of carbon from vermicompost and carbon stability when applied in the field are the next activities to be conducted.

Table E.4 Organic matter content of compost.

Vermicompost Source	% Organic Matter
Cattle manure:plant waste	17.22 24.14 17.36
Average	19.57
Food:Wood waste	26.5 20.4 24.24
Average	23.77

Manuscript of this study is being revised to submitted to the UPV Journal of Natural Science for publication. The paper has undergone peer review. Abstract was accepted for poster presentation at the 13th Vermicomposting Conference in the US in July 31-August 1, 2014 conference.

Dialogue/Consultation with Policy Makers and Technology Adoptors
3rd International Symposium in Vermitechnologies
Batangas City, Philippines
November 6-8, 2013

The impact of climate change in agriculture is primarily perceived by the farmers and other stakeholders as "drought, flooding, unpredictable weather and higher field temperature compared to previous years". This is a summary of the perceptions of the participants during the PANEL SESSION ON CLIMATE CHANGE: Dialogue on Science, Technology and Policy Interface in Climate Change Mitigation and Adaptation at the 3rd International Symposium on Vermitechnologies (ISVT-3) held at KAHARIAM Farms (which is the PMS1) on 6-8 November, 2013 (Fig. 5.61). The concept and objectives of the APN-LCI Research on Carbon Sequestration was presented back-to-back with the Farmer's Field School Curriculum for Climate Change Adaptation, a USAID funded project being implemented in the Philippines. During the Farmer's Forum, the need for the APN-LCI Research to interface with Farmers' Field School for Climate Change was seen as a means to disseminate a clear and simple knowledge of the mechanism relating climate change to the soils and the farming environment. To focus on the organic agriculture agenda, the Secretary of Agriculture, Sec. Proceso Alcala who participated in the dialogue and consultation forum, stressed the need for a scientific investigation on the value of vermitechnology, noting its positive effect on water conservation and natural soil fertility building due to earthworms, the soil biota and soil organic matter build-up. About 123 males and 81 females comprised of farmers, educators, agricultural and environmental workers, researchers, agripreneurs and policy makers from government, non-government and private sectors participated in ISVT-3. The Symposium was organized by four partners including the APN-LCI Research Project team aiming to provide basic information and updates in vermitechnologies not only in the Philippines but also in other countries.

Figure 6.1. Participants in the 3rd International Symposium of Vermitechnologies and the Dialogue on Science, Technology and Policy Interface in Climate Change Mitigation and Adaptation from different areas of the Philippines (Kahariam Realty and Farms Inc., Lipa City, Batangas, Now 6-8, 2013).

The following are the relevant reactions of the Panel and the participants during the dialogue.

Reaction 1 : A comprehensive information on farming and climate change; the presentation is full-depth on how dynamic the soils is and how important it plays as a sink of many nutrients, especially carbon. The information must be downloaded to a greater number of audience of farmers and waste management people.

Reaction 2 : It was a very good introduction on climate change as given by Prof. Ang Lopez and Dr Toledo. We know that climate change is now happening, just cannot be ignored in the Philippines. We are facing the fact that the Philippines is highly vulnerable because of being archipelagic, of being islands. We are at the verge of losing our islands and productive lands because of the climatic changes that are unpredictable. Like, we experience 24 typhoons which are abnormal; our normal average is about 20.

Reaction 3: The greenhouse gases that we are looking into are carbon dioxide, nitrous oxide and methane. What are there sources? Why do we have them?

Reaction 4: Regarding the carbon sequestration the use of vermitechnology, I think this vermitechnology or vermiculture is a great protection against greenhouse gas by sequestering the carbon. The research on vermicomposting is very timely, and if we can develop the information and measurement protocol, maybe we can also incorporate the carbon trading. Our Department - the Environmental Management Bureau and my Superior Mr. Albert Magalang is very active in the National Climate Change Program being the Secretary for the Clean Development Mechanism (CDM). CDM is one of the financial mechanisms under the Kyoto Protocol that enables developing countries to build their emission targets. It enables them to create projects to generate a certified emission reduction. I think that we can partner and share experiences and ideas, and integrate climate change study to our students. Our aim is to understand Climate Change more, you know and be able to protect our country and the world against climate change.

Reaction 5: I think the C- sequestration study is a worthy project because it can help us know how to face the challenges of climate change. With regards the C-sequestration through vermitechnologies, another consideration is to really look at holistically the CO2 generation- from production of the inorganic fertilizers like urea up to its transfer and application in the farm. We know for a fact that for every Kg of urea applied in the farm, about 27 Kg of C is generated. Therefore, with about 1.2 million rice rice farms in the Philippines, the generation is very high. The generation can be based on how much urea is used per hectare. We can imagine how big C emission would be avoided if we convert farming from conventional (using urea and other processed fertilizers) into organic farming system. Nitrous oxide from unused nitrogen from different fertilizers can be avoided.

Reaction 6: Regarding C-footprint, how much inorganic fertilizer use is reduced due to the build-up of organic matter? Account the amount of energy used in hauling of compost/raw materials, and the energy andlabor cost in processing compost.

Reaction 7: With regards the idea of carbon credits that could be produced with vermitechnology, well, it seems possible. But you know carbon credits and the manner how negotiations are ran. Actually, the problem is that developed (rich) countries refuse to change their lifestyles, so they just look for the small countries to trade. The rich countries will just buy whatever C- sequestration or avoidance they prove to have- and then treat it as their own. They will buy the Carbon credits from other countries, and just slightly reduce their C. In other words, they are not helping reduce greenhouse gas emissions directly, they just pay for the burden of the small countries or doing a serious work on carbon credit. Therefore, we should discourage carbon credits becauseits does not help in reducing the carbon emission. My suggestion is that this APN research on C-sequestration must not give much importance on the carbon credit potential of vermitechnology.

Reaction 8: The APN research will be useful for the improvement of the curriculum of the Climate Change Field School. It can provide a framework and perhaps, assistance in the fine tuning which could be as site specific. But what is important is that there is a framework where we could start on and could have a benchmark on how we could be implementing and adopt Climate Change mitigation technologies.

Reaction 9: Regarding microbiological activity, how will you assess this? Microbial count overtime or are you going to identify the specific microorganisms? For the CNS analyser, the Bureau of Soils and Water Management (BSWM) will have one early 2014. In 2015, we are planning to procure a total organic carbon analyser and also Biology for the identification of soil microorganisms. BSWM has been promoting vermicomposting since 2009.

Reaction 10: With regards the bacterial activity, Dr.Thuy Duong, raised biologist, according to her it is also possible that some other components in the system may have triggered the low level of bacterial population in the system. The formation of organic matter, especially the humic acid may have a reduction effect on the populations of bacteria. Microbial activity is one problem that we want to solve and if the BSWM can help us with that, we will be very very happy.

Reaction 11. The APN Research is relevant to address our concern on how many earthworms is needed within the area. For example, if Kahariam right now has ten tons of worms, how much carbon credit has it based on earthworms alone? Also, the 'precautionary principle' is important to apply including Climate Change. What is the trade-off?

Reaction 12. Your study is very interesting. Regarding the sending of samples to other countries, especially soils, it is the DENR PAWD, the Protected Area and Wild Life responsible for transport or for sending microbes and soils.

List of Topics Presented:

1. **Vermiculture Biotechnology**
   Dr. Rajiv K. Sinha
   Senior Lecturer
   Griffith University, Nathan campus, Brisbane, Australia

2. **Why Treat Soil Like Dirt**
   Robert John Blakemore

3. **Some Medicinal Properties of Traditional Formula Using Earthworm**
   Nguyen Thi My Nuong and Ho Huyn Thuy Duong
   University of Science – Ho Chi Minh City, Vietnam

4. **Vermiculture and Solid Waste Management: Experiences in Corporate Social Responsibility**
   Antonio de Castro
   President, Earthworm Sanctuary
   Project Director, Shumei Natural Agriculture Farms
   Vice President, Organic Producers and Trade Association

5. **Production and Use of Vermicompost and the "African Nightcrawler" (*Eudrilus euginae*) For Organic , Tilapia (*Oreochromis niloticus*) Culture**
   Rafael D. Guerrero III and Luzviminda A. Guerrero
   Aquatic Biosystems, Bay, Laguna
   Philippines

6. **Sewage Treatment by Vermifiltration with Synchronous Treatment of Sludge by Earthworms: a Low-Cost Sustainable Technology Over Conventional Systems with Potential for Decentralization**
   Rajiv K. Sinha, Gokul Bharambe and Uday Chaudhari
   Australia

7. **Growth of African Nightcrawlers (*Eudrilus euginae*) on Indigenous Substrates and Chemical Characteristics of their Vermicomposts**
   Jayson I, gula, Irene A. Francisco and Mark Stephen A, Guion
   Capiz State University, Capiz, Philippines

8. **Effect of Two Organic Inputs on the Growth and zYield of Pechay under DMMMDU-NLUC Condition**
   Agelita J. Prado

9. **Vermicomposting using Different Bedding Materials and Stocking Densities of African Night Crawlers (*Eudrilus euginae*)**
   Lilybeth G Sabadeo
   Iloilo State College of Fisheries – Dingle Campus
   Iloilo

10. **Vermichar: A Marriage Between Vermicompost and Biochar**
    Philip Camara
    Philippines

11. **Effects of Bamboo Biochar-Vermicompost Mixture on Test Plants**
    Naomi Carnaje[!], Ruben F. Amaparado Jr. and Robert M. Malalaan
    [1]School of Technolgy, University of the Philippines Visayas
    Philippines
12. **Vermicomposting: A Bridge to Our School Development**
    Emma B. Caballero
    Tagbak Sur Elementary School
    Oton, Iloilo
    Philippines

13. **Social and Psychological Implications of Vermiculture and Vermicomposting: Impact on health and Wellness**
    Elizabeth Protacio-de Castro
    Associate Professor, Department of Psychology
    University of the Philippines

14. **Potential for Anti-Blood Clotting Activity of Earthworm Extracts**
    Realm R. Alis[1] and Marilou J. Ang Lopez[2]
    [1] Aklan State University, Banga, Aklan
    [2] School of Technology, University of the Philippines Visayas
    Philippines

15. **Design, Construction and Performance Evaluation of a Vermisorter**
    Salvador C. Ballano Jr.
    Iloilo State College of Fisheries
    Iloilo, Philippines