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Agro-environmental Sustainability of Conventional and Organic Vegetable Production Systems in Tayabas, Quezon, Philippines

ABSTRACT

Environmental burdens of the different components of conventional and organic vegetable productions systems in Tayabas, Quezon were evaluated using the Life Cycle Assessment (LCA) approach. The study quantified the material inputs, outputs and emissions in a defined boundary, from land preparation to transport to market. Impact categories evaluated were global warming (GWP), acidification (AP), eutrophication (EP) and human toxicity (HTP) potentials based on the functional units of 1 kg and 1 ha production area.

Conventional vegetable farming contributions to global warming potential was 2.12E-01 kg CO_2 equivalent kg^{-1} of vegetable which was 43% higher than organic farming (1.21E-01 kg CO_2 equivalent kg^{-1} of vegetable). Acidification potential of conventional (4.76E-03 g SO_2 equivalent kg^{-1} of vegetable) was 23% higher than organic vegetable production (1.06E-03 g SO_2 equivalent kg^{-1} of vegetable). Organic farming contributed 3.03E+00 kg PO_4 equivalent kg^{-1} of vegetable potential eutrophication which was 16% higher than conventional with only 4.70E-01 kg PO_4 eq kg^{-1} of vegetable.

The application of chemical pesticides of conventional farms contributed to human toxicity potential calculated for both soil and air compartments. Cypermethrin had the highest total human toxicity in soil and air with 7.88E+06 g 1,4 DCB-eq ha^{-1} and 1.84E+02 g 1,4 DCB-eq ha^{-1}, respectively. Organic farms had zero human toxicity potential in this study since organic farmers did not use synthetic pesticides.

This study provided evidence on the possible environmental contributions to emissions of conventional and organic vegetable production systems.

Key words: *environmental burden, life cycle assessment, organic, vegetable production*

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INTRODUCTION

Agriculture is a significant contributor to land degradation and anthropogenic global greenhouse gas emissions (*Tubiello et al. 2007; Soussana 2014*). Agricultural interventions were small in scale and their impact was limited then, but today, it became more drastic in spatial scale and impact, thus, may be more threatening to all the life-support systems (*IISD 2013*).

In past decades, Philippine agriculture is very intensive since it is characterized by massive use of external inputs such as synthetic fertilizers and pesticide. Increasing population and food security led to the adoption of conventional farming system to increase yield and income which resulted to various environmental problems such as soil and atmospheric pollution and acidification, eutrophication of ground water, climate change and ozone layer depletion. In the long run, toxic and hazardous chemicals will eventually build-up in the soil, air and ground water and will cause harmful effects to the environment and will accumulate high level of toxicity that will be detrimental to human health (*IISD 2013*).

There are many studies and documentation (*Brentrup et al. 2001; Anton et al. 2005; Hayashi 2005*) on the impacts of conventional agricultural on the environment but not in comparison with other alternative production systems such as organic agriculture. Organic farming practices have been one of the most appropriate technologies to address environmental issues. It promotes sustainability through its environmentally sound and economically viable agricultural practices. It is widely practiced by upland and lowland farmers.

This study used the Life Cycle Assessment (LCA) to comprehensively evaluate conventional and organic production systems to minimize their potential environmental impacts. The result of the study will provide baseline information and will be useful in drafting appropriate policies that will protect the environment and human health.

The general objective of this study is to evaluate the environmental impacts of both conventional and organic vegetable production systems to further advance the existing agricultural practices that can contribute to protect the environment and will economically benefit the farmers. Specifically; this study will quantify the material inputs, outputs, emissions at each life cycle stage of every component, and their potential environmental burdens in the conventional and organic vegetable production systems; and analyze conventional and organic vegetable production systems to reduce their environmental burdens.

The life cycle assessment (LCA) is an objective process for evaluating environmental burdens that are associated with the process, product, or activity by identifying and quantifying materials and emissions to the environment and coming up with a possible environmental improvements (*Sven-Olof 2011*). It is a stepwise method comprising four major phases; the goal and scope definition, life cycle inventory analysis (LCI), life cycle impact assessment (LCIA) and lastly the interpretation and improvement assessment (**Figure 1**). The goal and scope definition identifies the functional unit and the system boundaries.

The defined goal and scope of the study guided the identification and quantification of all possible inputs and outputs related to the product under study. The inventory analysis was followed by the life cycle impact assessment which is the quantification of possible emissions throughout the life cycle of the vegetables grown in conventional and organic agriculture. The impact assessment also serves as the recognition, quantification, and summarization of the potential environmental impacts of the system under study and it also delivers essential information to facilitate evaluation (*ISO 14042 2000*).

Interpretation and improvement assessment produced recommendations for reducing environmental impact of vegetable production.

MATERIALS AND METHODS

Life Cycle Assessment (LCA)

Life Cycle Assessment is an approach that evaluates all stages of product's life. In this evaluation, environmental

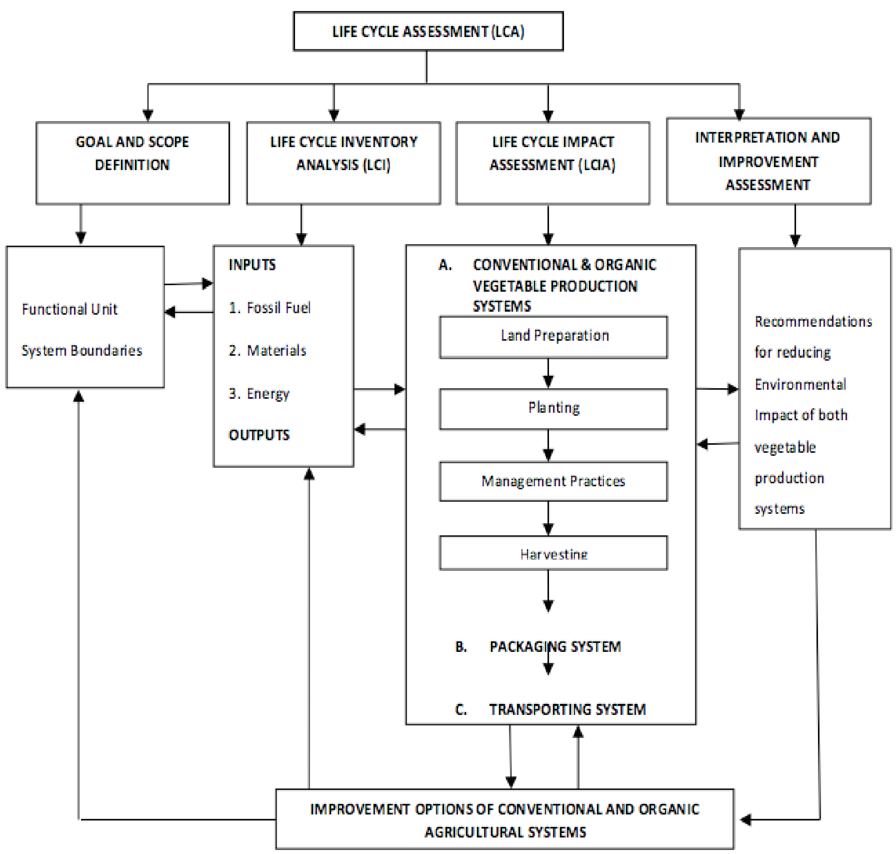

Figure 1. Conceptual framework of the life cycle assessment of conventional and organic vegetable production system (modified from *Gabertan 2008*).

impact from each stage is considered from raw material products, processing, distribution, use and disposal. The methodology considers not only the flow of materials, but also their outputs and environmental impacts (*Halberg 2004*). It is a collection and evaluation of the inputs, outputs and the potential environmental impacts of a production system throughout its life cycle (*Guinee et al. 2001*).

Goal and Scope of the Study

The study aims to assess the over-all environmental impacts of the different components of conventional and organic vegetable production systems in each life cycle stage, from planting to transport to the market. The functional unit which provides a basis for calculating inputs and outputs and was the unit of analysis defined for the study. The functional unit used in this study was set to 1 kg of packed vegetables and the main inputs and outputs were accounted for 1 ha of vegetable farm.

System boundaries include all inputs (materials, water and energy) and outputs (e.g. emissions) associated with conventional and organic vegetable production systems. Land preparation (land clearing, weeding, etc.), planting (direct or transplanted) and the cultural management practices involved in both production systems were considered. Harvesting, packaging and distribution to market were also part of the system boundaries.

Life Cycle Inventory Analysis

The outputs and emissions in each stage of production throughout the vegetables life cycle were identified and quantified. The actual consumption of resources such as labor, fertilizer (chemical or organic), planting materials (seeds and seedlings), pesticides or biosprays and harvesting in each life cycle stage for crop production systems (conventional and organic) were determined. Energy used for transportation as well as the emission rate was also identified.

Life Cycle Impact Assessment

At this stage, data collected during the Life Cycle Inventory (LCI) were processed and translated in terms of environmental impacts of the system (*Guinee et al. 2001*). The four types of impact assessment categories considered in this study were:

Global Warming Potential (GWP). The rate of fossil fuel consumed for the whole crop production was used to compute the greenhouse gas emissions for each crop. The formula from the *United States Environmental Protection Agency (2005)* was used to obtain the CO_2 emission.

Carbon dioxide emission (kg) = diesel used (L) * (2778 g carbon/3.74 L diesel) * 99 (CO_2C^{-1})

Emissions were converted to CO_2 equivalents using the global warming potential (GWP) index. The GWPs for 100 years equal to 1 was used (*Narayanaswamy and Altham 2003*). The formula below was used to determine the GWP of CO_2 based on (*Guinee et al. 2001*).

Global Warming Potential of CO_2= Emission of CO_2 * GWP100 characterisation factor

Acidification Potential (AP). The energy such as diesel in liters consumed for vegetable production including transportation was used for the calculation of acidification potential. The formula used to compute the amount of sulphur dioxide (SO_2) emission from diesel (*Htein 2012*) is as follows:

SO_2 Kg^{-1} = L * (Density of Diesel, kg L^{-1}) * (Sulphur content in diesel, SO/S)

Where: L is the liters of diesel used
Density of diesel = 85 g L^{-1}
Sulphur content of diesel = 0.5% ~ 0.05

The computed SO_2 emitted was used to obtain the atmospheric acidification potential. The formula (*Guinee et al. 2001; Narayanaswamy and Altham 2003*) was used to compute the acidification potential over 100 year's life span with characterisation factor equal to 1 (*Halberg 2004*).

Atmospheric Acidification Potential of a substance= Emission of the substance * Atmospheric Acidification Potency factor of a substance

Eutrophication Potential (EP). The data on the amount of nutrient N and P available in conventional and organic vegetable production systems were collected. This study considered the NO_3 and PO_4 with eutrophication factor of 0.1 and 1, respectively (*Heijungs et al. 1992*). The eutrophication potential expressed as kg $(PO_4)^{3-}$equivalent was computed based on the formula (N*arayanaswamy and Altham 2003*):

Eutrophication factor of a substance = Emission of a substance * Eutrophication potency factor of a substance

Human Toxicity Potential (HTP). The human toxicity impact category covers the impacts on human health of toxic substances present in the environment. The data used was the total amount of pesticide (volume, frequency of use, active ingredient of the pesticides) applied throughout the vegetable crop season which was computed using the formula (*Gabertan 2008*):

Amt. of pesticides Applied (g) = Active ingredient L^{-1} * Vol. of pesticides used *Frequency of use

The category indicator for the human toxicity impact category is measured in kg of 1, 4 Dichloro Benzene (DCB) equivalents. The human toxicity of a substance was calculated using the formula (*Narayanaswamy and Altham 2003*):

Human toxicity of a substance = ∑ {emission of the substance * Human toxicity potency factor for the substance}$_{\text{air, water, agri-soil}}$

Primary Data Collection

For conventional and organic vegetable production systems, representative farmers were interviewed. For the organic production system, 23 members (77%) of the SAMA PO KATA, an organic farmers' organization in Tayabas were interviewed. Conventional farmer respondents were randomly identified from the list of the conventional vegetable farmers in the whole of Tayabas provided by the City Agriculture office. There were about 159 conventional vegetable farmers in the whole municipality of Tayabas during the study and the calculated sample size of the study was 87 farmers (55%). The structured questionnaire was pre-tested and was used to gather all possible information needed for the analysis. Focus group discussion (FGD) and key informant interview (KII) were conducted to gather other significant data.

Interpretation/ Improvement Analysis

The Life Cycle Interpretation is a systematic technique to identify, quantify, check, and evaluate information from the results of the inventory (LCI) and impact assessments (LCIA), and communicate them effectively (*SAIC 2006*). The results of interpretation must be the conclusions and possible recommendations in improving the production systems under study.

RESULTS AND DISCUSSION

Location of the Study Area

The study was conducted in Tayabas, a 6th class component city (as of 2012) of the Province of Quezon in Luzon (**Figure 2**) (*OCPDC Tayabas 2012*). Tayabas is geographically located at 140 50' Latitude East-Southeast of Mt. Banahaw and positioned between 140 01' 40.3" North Latitude and 1210 36' 54.5" East Longitude. It is bounded on the North by Lucban; Mauban on the East; Pagbilao to the South-East; Lucena City to the South; and Sariaya and Mt. Banahaw to the West. Tayabas is located at the foot slope of Mt. Banahaw with highest elevation of about 1,980 m above sea level (m asl) and the lowest is 17.54 m asl. The slope of almost 8,669 ha (38% of the total land area) is nearly level to undulating, good for farmlands and suited for seasonal inter-tilled crops. The five (5) major soil types are: macolod clay loam, ibaan loam, bolinao loam, luisiana sandy clay loam and mountain soil. Macolod clay loam has the largest coverage with a total area of 13,908.46 ha (60%) of the whole Tayabas.

The total land area of Tayabas is 23,095 ha divided into urban (82.15 ha) and rural (23,012.85 ha). Tayabas has 66 barangays 19 of which, are within the poblacion; 11 barangays are booming sub-urban and 36 barangays are classified as rural areas. As of May 1, 2010 the total human population of Tayabas is 81,112, 51% male and 49% female with growth rate of 2.57% (O*CPDC Tayabas 2012*). The main source of livelihood is agriculture, hunting and forestry (32%). Crops such as rice, coconut, root crops and vegetables are the primary products.

Socio-Economic and Demographic Profile of Farmer Respondents

All the 23 organic farmers are more than 40 years old and 17 respondents (74%) are older than 61 years old (**Table 1**). Among the conventional respondents, 61% are more than 40 years, while 39% are younger than 40 years old. Hence, there are older people involved in farming. In terms of gender, 65% and 80% of the respondents are male in organic and conventional group, respectively.

Educational attainment is one of the important parameters to look into when analysing the agricultural production system. Among the organic and conventional farmer respondents, 74% and 94%, respectively are either elementary or high school graduate. The highest educational attainment for all the respondents is college graduate with 26% and 6% for organic and conventional farmers, respectively.

More than half (57%) of the organic farmer respondents own the land they till against only 5% for conventional farmer respondents. The tenants, particularly the conventional farmers practice the "one-fifth" sharing system, i.e., for every five parts of harvest, one part is given to the land owner. Land ownership is important in farmers' decision making because farm practices, technologies and attitude in farming are usually for long-term benefit. The vegetable farmers in Tayabas are considered small-scale farmers because 90% of both

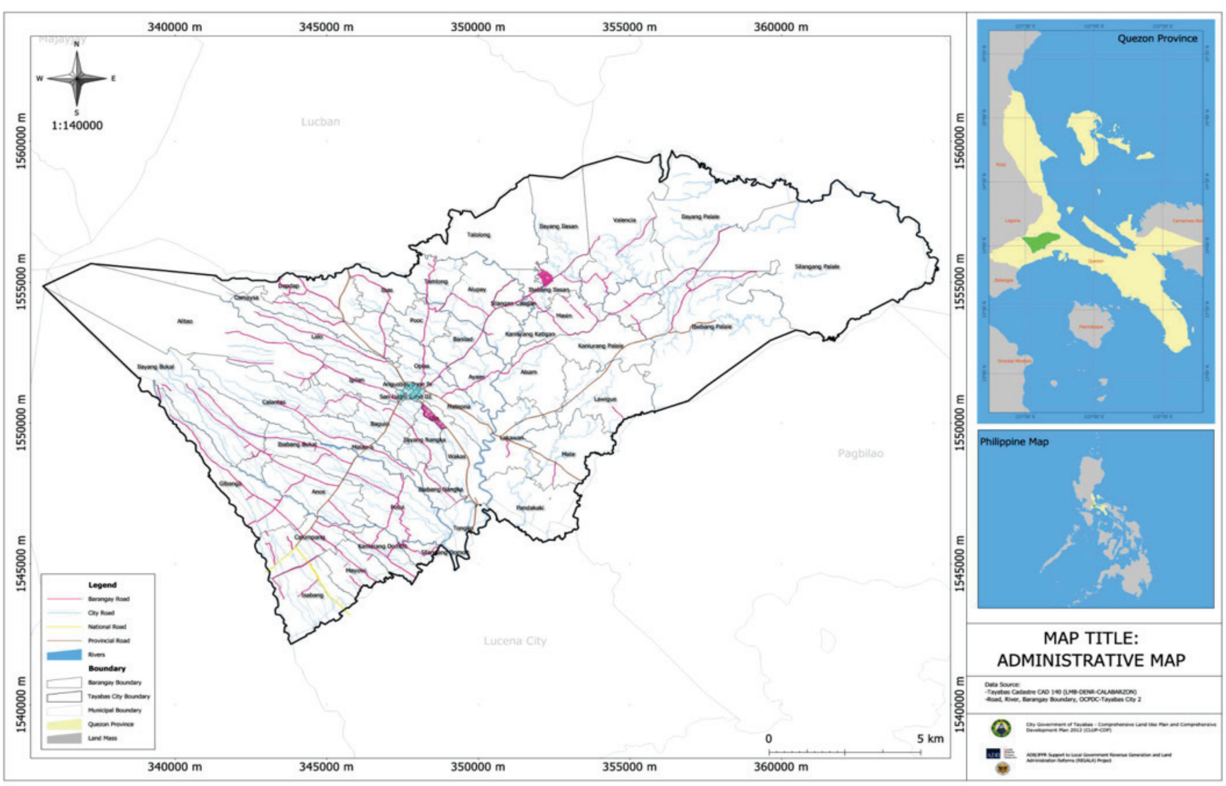

Figure 2. Administrative map of Tayabas City, Province of Quezon, Philippines 2015 (Source: City Government of Tayabas (OCPDC), scale: 1:120000).

organic and conventional farmer respondents, whether owner or tenant, are tilling only ≤ 0.5 ha.

All organic farmers and 93 % of the conventional farmer respondents rely on their own resources for capital for their farming activities inputs. The remaining 7% of conventional farmers obtain their loans (mainly for agrochemicals) from the agri-businesses or stores located in Tayabas or in nearby town.

Life Cycle Inventory (LCI) of Organic and Conventional Vegetable Production Systems

The study considered the farm level as unit of analysis especially in the inventory. Due to the diverse cropping patterns of both organic and conventional farmer respondents, they were grouped into three based on the number of crops planted and marketed as follows: a) planting and selling only 1 crop; b) planting and selling 2 crops; and c) planting and selling 3 or more crops (**Table 2**). The grouping was used in the inventory analysis (inputs, outputs, etc.)and impact assessment of both production systems.

There are at least 10 types of vegetable crops planted by the organic farmers. These are bitter gourd, baguio beans, bottle gourd, eggplant, ginger, lettuce, okra, patola, squash, string beans, tomato. Baguio beans, eggplant, and string beans are planted during the months of February to May when rainfall is evenly distributed. Tomato, squash, bitter gourd and bell pepper are planted in two cropping seasons (February to June and October to December) because of its higher market price during these months. Ginger is planted after the rainy months (June to August) to get optimum yield.

For conventional vegetable farming, the types of vegetables planted are bell pepper, bitter gourd, celery, chayote, eggplant, ginger, mustard, okra, pechay, radish, spring onion, spinach, string beans, tomato and turmeric (**Table 2**). Out of these 15 types of vegetables, the most common are spring onion, eggplant and pechay. Spring onion is planted by 62% of conventional farmers, eggplant is planted by 10% of conventional farmers and pechay is planted by 9% of conventional farmers. Other types of vegetables are planted by only 6% of farmer respondents. Farmers prefer spring onion because it can be harvested every after two months and they can plant at most four croppings in a year. Planting of eggplant, string beans, celery, bitter gourd and tomato depend on the seasonality and market demand.

The land area for organic vegetable production is cleared manually (60%) using various tools such as bolo, spade and rake. Others (40%) used carabao-drawn plow to clear and cultivate the soil. The collected weeds were mixed it with animal manure and composted, while others were just allowed to dry up in the field. Land preparation

Table 1. Socio-economic and demographic characteristics of respondents of organic and conventional vegetable growers in Tayabas, Quezon, Philippines, 2015.

Variables	Organic		Conventional	
	Frequency	Percentage	Frequency	Percentage
Age Group				
≤30	-	-	8	9
31-40	-	-	26	30
41-50	1	4	26	30
51-60	5	22	19	22
≥61	17	74	8	9
Total	23	100	87	100
Gender				
Male	15	65	70	80
Female	8	35	17	20
Total	23	100	87	100
Educational Attainment				
Elementary	8	35	39	45
High School	9	39	43	49
College	6	26	5	6
Total	23	100	87	100
Tenure and Land Holdings				
Own	13	57	4	5
Tenant	10	43	83	95
Total	23	100	87	100
Farm Size (ha)				
≤ 0.5	21	91	78	90
≥ 0.75	2	9	9	10
Total	23	100	87	100
Capital Sources				
Own	23	100	81	93
Loan	-	-	6	7
Total	23	100	87	100

Table 2. Farming characteristics of organic and conventional vegetable farmer respondents in Tayabas, Quezon, Philippines, 2015.

Variables	Organic			Conventional		
	Number of crops			Number of crops		
	1	2	≥3	1	2	≥3
Number of Farms	15	4	4	73	5	9
Farm Area (ha)	2.26	0.5	1.57	20.62	1.53	5.33
Crops Planted	Baguio beans (*Phaseolus vulgaris*); Bitter gourd (*Momordica charantia*); Bottle gourd (*Lagenaria siceraria*); Eggplant (*Solanum melongena*); Ginger (*Zingiber officinale*); Lettuce (*Lactuca sativa*); Okra (*Abelmoschus esculentus*); Patola (*Luffa aegyptiaca*); Squash (*Cucurbita maxima*); String beans (*Phaseolus lunatus*); and Tomato (*Solanum lycopersicum*)			Bell pepper (*Capsicum*); Bitter gourd; Celery (*Apium graveolens*); Chayote (*Sechium edule*); Eggplant; Ginger (*Zingeber officinale*); Mustard (*Brassica sinapis*); Okra (*Abelmoschus esculentus*); Pechay (*Brassica chinensis*); Radish (*Raphanus sativus*); Spring onion (*Allium* sp.); Spinach (*Spinacia oleracea*); String beans (*Phaseolus lunatus*); Tomato (*Solanum lycopersicum*); and Turmeric (*Curcuma longa*)		

is followed by vermicompost and animal manure application. To improve soil fertility, organic farmers apply vermicompost at about 215.6 g (N,P,K) kg^{-1} of vegetables and animal manure at 153 g (N,P,K) kg^{-1} of vegetables (**Table 3**). Farmers produced their own vermicompost and others purchased from their organization.

Vegetables are direct seeded and transplanted following the standard planting distance. To produce a kilogram of organic vegetables the respondents used 0.17 g of *Galaxy F1* hybrid seed for bitter gourd, 3.84 g of *Sandigan* for string beans, 0.09 g of *Morena F1* for eggplant, 0.08 g of *Apollo* for tomato, and 12.10 g of *Smooth green* for Okra.

Post planting management activities include weeding, trellising, pest and disease monitoring and management, and organic fertilization. Weeding is done mostly twice per cropping. Some of the respondents hire labor at PhP 300 d^{-1}. For trellis, farmers used poles usually kakawate (*Gliricidia sepium*) and bamboo poles. Strings are connected to support the plants especially during fruiting stage. Trellises help maximize leaf light display to maximize photosynthesis for better development and higher fruit production. The energy inputs are important because labor cost is high at PhP 250 md^{-1} to PhP 300 md^{-1} for weeding.

Land preparation of vegetables planted by conventional farmers started from land clearing and making raised bed (**Table 4**). Among the respondents, 75% apply glyphosate herbicide (commercial names: *Spit Fire, Sharp shooter, Power, Demolition*), *Paraquat* (Gramoxone), Butachlor (Machete) and *2, 4-D*. The respondents apply herbicide to speed up the land clearing process and to save on labor cost.

Farmers apply animal manure, usually chicken dung during land preparation, a week before planting. String beans, bitter gourd, okra, and spring onion are direct seeded. Transplanting is commonly practiced in small-seeded

Table 3. Material input to production system kg^{-1} of organic vegetables in Tayabas, Quezon, Philippines, 2015.

Vegetables Planted	Inputs (g kg^{-1} of vegetables)				
	Seeds	Vermicompost (N,P,K)	Animal manure (N,P,K)	String	Trellis (piece ha^{-1})
Baguio Beans	19.61	25.75	5.61	2.6	300
Bitter Gourd	0.17	10.49	18.03	8.3	710
Bottle Gourd	38.02			3.2	53
Eggplant	0.09	12.36	10.45	5.4	358
Ginger	49.43	29.50	13.60		
Lettuce	0.76	73.75	13.60		
Okra	12.10	26.82	37.09		
Squash	0.11	4.94	1.50		
String Beans	3.84	4.61	10.53	4.6	407
Tomato	0.08	27.44	42.70	2.1	237
TOTAL	124.21	215.66	153.11	26.2	2065

Table 4. Material inputs kg^{-1} of vegetables used by conventional vegetable farmer respondents in Tayabas, Quezon, Philippines, 2015.

Vegetables Planted	Inputs (g kg^{-1} of vegetables)				
	Seeds	Vermicompost (N,P,K)	Animal manure (N,P,K)	String	Trellis (piece ha^{-1})
Bell Pepper	0.303	24.30	33.56	2.30	450
Bitter Gourd	0.183	23.79	18.56	1.89	203
Celery	0.370	8.46	7.70		
Chayote	0.142	1.12	0.09	0.31	1058
Eggplant	0.004	3.81	3.00	0.21	331
Ginger	3.226		10.88		
Mustard	0.108	8.73	10.06		
Okra	5.000	46.00			
Pechay	0.024	2.40	2.10		
Radish	0.004	2.24	3.29		
Spring Onion	0.034	0.79	0.81		
Spinach	2.151				
String Beans	0.412	14.36	8.24	0.56	291
Tomato	0.011	6.03	2.14	0.33	240
Turmeric	4.839		10.88		
TOTAL	16.810	142.03	111.29	5.6	2572

vegetables such as pechay, eggplant and tomato.

The conventional farmers used the following amounts of seeds to produce a kg of vegetable for different crops: for direct seeded vegetables; 0.41 g for string beans, 0.18 g for bitter gourd, 5 g for okra, 0.03 g for spring onion seeds, 0.14 g for chayote; and for transplanted vegetables; 0.02 g for pechay and 0.01 g for both eggplant and tomato (**Table 4**). Trellising is used to support string beans, tomato, eggplant, bell pepper, bitter gourd for ease in monitoring, pest control and also for ease of harvesting. Farmers use bamboo poles with mean of 429 pcs ha^{-1} and string at 6 g ha^{-1}.

At early vegetative stage of vegetables, conventional farmer respondents apply additional animal manure or chicken dung at 111.29 g N,P,K. Inorganic fertilizers (142.03 g N, P, K) are also used to increase crop productivity. Seeds and fertilizers are purchased from suppliers in Tayabas and from suppliers visiting the area.

Land preparation is commonly done manually and this requires about 11 md ha^{-1}. Fertilization requires 14 md ha^{-1} and harvesting requires 54 md ha^{-1}. Manpower requirement depends on the number of crops planted. Farmers planting only one crop need 128 md ha^{-1}, while farmers planting more than 3 crops simultaneously spend more to hire laborers at 167 md ha^{-1}.

Life Cycle Impact Assessment

The Life Cycle Impact Assessment (LCIA) is important in determining the potential human health and environmental impacts of the different agricultural production systems. The different impact categories considered in this study are: Global Warming Potential and Acidification Potential (air pollution), Eutrophication Potential (water pollution) and Human Toxicity Potential (human health).

Global Warming Potential (GWP)

The global warming potential was computed using the amount of diesel used from land preparation to marketing the vegetables produced. In organic farming, growing more than 3 crops resulted to higher GWP ha^{-1} with 23.64 kg CO_2-equivalent than when only one or two crops are grown (**Table 6**). Mean GWP ha^{-1} is higher in conventional farms (26.25 kg CO_2-equivalent) than in organic farms (10.25 kg CO^2-equivalent). The higher usage of diesel fuel especially for both farming systems planting 3 or more crops is because of not synchronized harvesting and marketing of the different vegetables, i.e., the crops are not sold at the same time. On the other hand, in organic farms with only one crop, the usage of diesel is much lower at 6.4 L per farm with lowest CO_2 emission of only 2.54 kg CO_2-equivalent ha^{-1}.

For conventional farming system, planting 3 or more crops resulted to the highest GWP (95.4 kg CO_2 emission) per farm which is 36% higher than the CO_2 emission of organic farms with the same number of crops. The conventional farms used higher amounts of diesel at 21.31 L, compared with organic farms at 8.92 L (**Table 5**). This was because conventional farmers delivered their produced individually to the market. While organic farmers have thefarmers' cooperative that sells the produce to the market thus saving on diesel fuel.

Table 5. Diesel fuel input of organic and conventional vegetable production systems (L ha^{-1}) planting and selling 1, 2 and ≥3 crops in Tayabas, Quezon, Philippines, 2015.

Variables	Organic			Conventional		
	Number of crops			Number of crops		
	1	2	≥3	1	2	≥3
Diesel Input per farm (L)	6.4	13.25	22.88	9.9	18.4	36
Diesel Input L Ha^{-1}	0.96	1.72	8.92	2.77	5.63	21.31
Diesel Input kg^{-1} of vegetable	0.017	0.039	0.065	0.013	0.047	0.15

Table 6. Global warming potential (kg CO_2 equivalent) of organic and conventional vegetable farming systems in Tayabas, Quezon, Philippines, 2015.

Variables	Organic			Conventional		
	Number of crops			Number of crops		
	1	2	≥3	1	2	≥3
Mean farm area (Ha)	0.15	0.13	0.13	0.28	0.306	0.592
Total Diesel Used per farm (L)	6.4	13.25	13.25	9.9	18.4	36
C02 Emission (kg)	16.96	35.11	35.11	26.30	48.76	95.40
GWP ha^{-1}	2.54	4.56	4.56	7.36	14.92	56.48
GWP kg^{-1} of vegetables	0.017	0.039	0.039	0.013	0.047	0.152

The conventional vegetable production system had higher GWP kg^{-1} of vegetables at 2.12 E-01 kg CO_2-equivalent compared to the organic vegetable production system with GWP of 1.21 E-01 kg CO_2-equivalent kg^{-1} of vegetables.

Acidification Potential (AP)

The sulphur dioxide emission (expressed as g SO_2 equivalent) for both organic and conventional vegetable production systems was determined using the fuel inputs from land preparation to marketing of the vegetables. Conventional farms planting 3 or more crops had the highest AP at 2.81 g SO_2 equivalent ha^{-1} followed by 1.18 g SO_2 equivalent ha^{-1} of organic farms planting 3 or more crops (**Table 7**).

Regardless of the number of crops planted, conventional vegetable farms uses diesel. The SO_2 equivalents of the conventional farms planting 1 and 2 crops are also higher than organic at 0.37 g SO_2 -equivalent and 0.74 g SO_2 -equivalent, respectively. Acidification potential in conventional farms with 3 or more crops is the highest with 0.0118 g SO_2 -equivalent kg^{-1} of vegetable. The higher is the acidification potential, the higher is the system's contribution of SO_2 which is harmful to the atmosphere.

The computed acidification potential is dependent on the amount of diesel fuel used by farmers for marketing their produced. The acidification potential of conventional leek is 18% higher than the organically grown leek (*De Backer 2009*). Burning of fossil fuel released harmful pollutants such as sulphur dioxide (SO_2) and oxides of nitrogen to the atmosphere and their combination with other molecules results in acidification of ecosystems.

Eutrophication Potential (EP)

The eutrophication potential expressed as kg PO_4-equivalent was determined for both conventional and organic farming systems using the nitrogen and phosphorusinputs, N and P uptakes and yield of farmers. The present study considered only the crops that are common for both conventional and organic vegetable production systems. They are eggplant, string beans and tomato. The nitrogen (N) balance in conventional vegetable production of tomato (2459.7 kg ha^{-1}) is higher than that of eggplant (1830.8 kg ha^{-1}) and of string beans with 1707.7 kg ha^{-1} (**Table 8**). The N and P balance was computed by determining the N and P available (kg ha^{-1}) and N and P uptake (kg ha^{-1}) of eggplant, string beans and tomato in both conventional and organic farming systems.

Available N and P were from the amount of fertilizers (e.g., vermicompost, animal manure, urea, complete fertilizer, etc.) applied by both organic and conventional vegetable farmers. In the absence of detailed soil analysis, the amount of N and P native in the soil of Tayabas was obtained from the amount of N and P present in the first 20 cm layer of Ibaan series converted into kg ha^{-1} (*Monsalud et al. n.d.*). The study assumed that the amount of N and P native is the same for both conventional and organic farms. For N and P uptake of eggplant, string beans and tomato; data from published studies of *Hedge* (*2012*)*; Htein* (*2012*) *and IPNI* (*2015*) were used.

Highest N balance was recorded in organic tomato at 2600.6 kg N ha^{-1}, followed by tomato in conventional farm with 2459.7 kg N ha^{-1}, and organic eggplant (2446.6 kg ha^{-1}). The N balance ha^{-1} is higher in organic production because of its lower yield and possible N build-up in the soil due to repeated and more than 7 year application of organic compost and animal manure. The nitrogen balance in terms of kg^{-1} of vegetable is highest in organic string beans (1.194 N kg^{-1}) followed by organic tomato and organic eggplant at 1.150 N kg^{-1} and 0.650 N kg^{-1}, respectively.

The N uptake by plants is in the form of nitrate (NO_{3-}) which is very mobile in soils. The crop uptake is the most desirable pathway for nitrogen, however not all available N is used by plants (*Van Es n.d*). Nitrogen losses are serious economic and environmental concerns. Environmental concerns include the leaching of soil nitrate to groundwater, excess N in runoff, and losses of nitrous oxide, a potent greenhouse gas (*SARE 2012*). Some management strategies that can reduce nitrogen losses are maintaining good drainage, e.g., planting in raised beds, building and maintaining soil health e.g., increase organic

Table 7. Acidification potential of organic and conventional vegetables in Tayabas, Quezon, Philippines, 2015.

Variables	Organic			Conventional		
	Number of crops			Number of crops		
	1	2	≥3	1	2	≥3
Mean farm area (Ha)	0.15	0.13	0.39	0.28	0.31	0.59
Total Diesel Used (L)	6.4	13.25	22.88	9.9	18.4	36
$S0_2$ Emission (kg)	0.84	1.75	3.01	1.30	2.42	4.74
AP g SO_2 Equivalent Ha^{-1}	0.13	0.23	1.18	0.37	0.74	2.81
AP kg^{-1} of vegetables	0.00016	0.00041	0.00261	0.00050	0.00190	0.01188

matter, and incorporating or mixing the organic manures or compost into the soil during application (*Van Es n.d*). These management practices are already practiced by organic farmers, thus, higher amount of excess N in the organic farms have lower potential environmental loss.

The conventional vegetable farming had higher mean available phosphorus (35.04 kg ha^{-1}) because farmers applied additional inorganic fertilizers (**Table 8**). Organic farmers on the other hand applied high amount of organic fertilizers (vermicompost and animal manure), thus, higher available P particularly in tomato (46.57 kg ha^{-1}). Highest P uptake was observed in conventional string beans (28.37 kg ha^{-1}) because of higher yield. Organic farming had lower P uptake hence 18% higher P balance than the conventional system. The higher amount of P especially in organic farms may be due to the significant build-up of P levels in the soil due to repeated applications since conversion to organic agriculture.

The P balance kg^{-1} of vegetable is higher in organic vegetable production. Highest P balance was observed in organic tomato with 0.0202 kg^{-1} of vegetable and the lowest was in conventional eggplant (0.0012 kg P) kg^{-1} of vegetable (**Table 9**). The total P balance of organic in terms of kg^{-1} vegetable is 0.031 kg higher than the conventional vegetable.

The computed N and P balance were used to determine the nitrate (NO_3) and phosphate (PO_4) equivalent kg^{-1} of vegetable. Among the production systems, the organic farming had 84% higher eutrophication potential (0.334 kg PO_4 equivalent kg^{-1} of vegetable) than the conventional (0.051 kg PO_4 equivalent kg^{-1} of vegetable) because of higher organic fertilizer application and lower yield.

Organic tomato production also had highest eutrophication potential with 0.135 kg PO_4-eq kg^{-1} of vegetable among other vegetables. Phosphorous is available as mainly dissolved phosphate in soil water but little is present in solution even in fertile soils. Compared with nitrogen, phosphorus is not mobile. The primary losspathways for P are runoff and soil erosion. Reducing phosphorus losses includes keeping the soil covered e.g.,

Table 8. Nitrogen (N) and Phosphorus (P) available, uptake and balance in conventional and organic vegetable production areas in Tayabas Quezon, Philippines, 2015.

Vegetables Planted	N Available (N kg ha^{-1})	N Uptake (N kg ha^{-1})	N Balance (N kg ha^{-1})	N Balance (N kg^{-1} of veg)
Conventional				
Eggplant	2636.2	805.4	1830.8	0.068
String Beans	2653.2	945.5	1707.7	0.181
Tomato	2572.9	113.2	2459.7	0.217
Organic				
Eggplant	2559.6	113.0	2446.6	0.650
String Beans	2524.4	195.1	2329.2	1.194
Tomato	2623.2	22.6	2600.6	1.150
Vegetables Planted	**N Available (N kg ha^{-1})**	**N Uptake (N kg ha^{-1})**	**N Balance (N kg ha^{-1})**	**N Balance (N kg^{-1} of veg)**
Conventional				
Eggplant	39.19	8.04	31.15	0.0012
String Beans	41.51	28.37	13.14	0.0014
Tomato	24.42	4.53	19.89	0.0018
Organic				
Eggplant	29.94	1.140	28.80	0.0076
String Beans	20.40	5.854	14.55	0.0075
Tomato	46.57	0.904	45.67	0.0202

Table 9. Eutrophication potential of NO_3 and PO_4 from fertilizer applied for conventional and organic vegetable production systems in Tayabas Quezon, Philippines, 2015.

Vegetables	Eutrophication Potential (kg PO_4 equivalent kg^{-1} vegetable)					
	Organic			Conventional		
	NO_3	PO_4	Total	NO_3	PO_4	Total
Eggplant	0.650	0.0076	0.0726	0.0068	0.0012	0.0080
String Beans	0.119	0.0075	0.1269	0.0181	0.0014	0.0195
Tomato	0.115	0.0202	0.1352	0.0217	0.0018	0.0235
Total	0.299	0.0353	0.3347	0.0466	0.0044	0.0510

mulching, cover cropping; and increasing soil infiltration capacity by building and maintaining soil health (*Van Es n.d*).

Overall, significant amount of N and P that can potentially contribute to eutrophication is observed in organic farms (84%). However, strategies for reducing N and P losses from the soil-plant system have been practiced of organic farmers more than 7 years ago. Thus, potential losses of N and P, whether through leaching, runoff or soil erosion in organic farms are still low because of the good soil management practices such as mulching, cover cropping, and multiple cropping.

Human Toxicity Potential (HTP)

The human toxicity potential in soil and air were calculated using the data on the chemical pesticide applied by the conventional vegetable farmer respondents (**Table 10**). There are 20 brands of pesticide used; 6 are herbicides, 2 fungicides and 12 insecticides. The active ingredients of the pesticides were obtained from the list of registered pesticides published by the Department of Agriculture in 2010. Human Toxicity Factors (HTP) of the active ingredients were obtained from the LCA Operational Guide (*Guineeet al. 2001*) expressed as g 1,4 DCB equivalent. The study considered only the air and soil pollution due to limited data to compute the human toxicity in water. The study assumed that 5% and 70% of the applied pesticides are spread in air and soil, respectively (*Gabertan 2008; Guinee et al. 2001*).

The human toxicity emission in soil shows that among eight pesticides applied by farmers planting only 1 crop Carbofuran had the highest total human toxicity with 3.06E+06 g 1,4 DCB-eq ha^{-1}. It was followed by Cypermethrin with brand name *SuperM* with 5.97E+05 g 1,4 DCB-eq ha^{-1} and followed by 2,4-D Amine (5.26E+05 g 1,4 DCB-eq ha^{-1}) and Methomyl (1.39E+04 g 1,4 DCB-eq ha^{-1}). Farmers planting 2 crops applied only 2 types of pesticides such as Methomyl with 3.25E+04 g 1,4 DCB-eq ha^{-1} and Glyphosate with brand names *Power* (1.12E+02 g 1,4 DCB-eq ha^{-1}) and *Sharp shooter* (6.05E+01 g 1,4 DCB-eq ha^{-1}).Pesticide applications of farmers planting 3 or more crops are relatively higher than farmers planting 1 and 2 crops, respectively. Among the eight active ingredients of pesticides, Cypermetrin (*Supermetrin*) had the highest human toxicity potential 7.28E+06E g 1,4 DCB-eq ha^{-1} followed by Carbofuran (3.92E+06 g 1,4 DCB-eq ha^{-1}) and Carbaryl (1.69E+04 g 1,4 DCB-eq ha^{-1}).

The human toxicity potential (HTP) in the air shows that Carbofuran had the highest HTP applied by farmers planting ≥3 crops with 4.00E+04 g 1,4 DCB-eq ha^{-1}. It was followed by *Supermetrin* (4.00E+04 g 1,4 DCB-eq ha^{-1}) and Chlorpyriphos (8.82E+02 g 1,4 DCB-eq ha^{-1}) (**Table 10**). Farmers planting only 2 crops applied Methomyl (3.35E+02 g 1,4 DCB-eq ha^{-1}) and Glyphosate (*Power*) 1.65E+00 g 1,4 DCB-eq ha^{-1}. Pesticide application of farmers planting only 1 crop is lower than farmers planting 2 and3 or more crops, respectively. Among the active ingredients, Carbofuran had the highest HTP with 3.13E+04 g 1,4 DCB-eq ha^{-1} followed by 2,4-D Amine (5.28E+03 g 1,4 DCB-eq ha^{-1}) and Cypermethrin (1.39E+03 g 1,4 DCB-eq ha^{-1}).

Sensitivity Analysis

The LCA is an important decision-making tool to check the robustness of the results. This can be done through sensitivity analysis as part of the interpretation

Table 10. Human toxicity emission in the soil and air of pesticides used in conventional vegetable production (g 1,4 DCB equivalent) in Tayabas, Quezon, Philippines, 2015.

Variables	Human Toxicity Potential (HTP)					
	Number of crops			Number of crops		
	1	2	≥3	1	2	≥3
Glyphosate						
SpitFire	4.70E+00		3.36E+00	6.94E-02		4.96E-02
Sharp Shooter	1.93E+01	6.05E+01	1.01E+01	2.84E-01	8.93E-01	1.49E-01
Power	1.52E+01	1.12E+02		2.24E-01	1.65E+00	
Demolition	7.98E+00			1.18E-01		
Cyphermetrin						
SuperM	5.97E+05			1.39E+03		
Supermetrin			7.28E+06			1.70E+04
Paraquat	4.45E+01		1.19E+01	6.57E-01		1.75E-01
2,4-D Amine	5.26E+05			5.28E+03		
Methomyl	1.39E+04	3.25E+04		1.43E+02	3.35E+02	
Carbofuran	3.06E+06		3.92E+06	3.13E+04		4.00E+04
Carbaryl	2.67E+02		1.69E+04	2.91E+00		1.84E+02
Chlorpyriphos	1.39E+03		8.23E+03	1.49E+02		8.82E+02

phase. Sensitivity analysis assesses the influence on results of variations in process data, model choices and other variables. In this step, these changes are deliberately introduced in order to establish the strength of the results with regard to these variations (*Guinee et al. 2001*). The objective of the sensitivity check is to evaluate the reliability of the results by determining whether the uncertainty in the significant issues affect the decision-maker's ability to confidently draw comparative conclusions (*Curran 1996*).

In the present study, the major data that highly influences the results of impact assessment are the system boundary in relation to fuel consumption and the amount of fertilizers and pesticides applied. Majority of the published articles on LCA in agricultural production systems used the 'cradle-to-farm gate' as the system boundary (*Harris and Narayanaswamy, 2009*). The system boundary defined in this study is from land preparation to marketing for both conventional and organic vegetable production systems. The inventory analysis and impact assessments were done within the defined system boundary. In the present study, diesel fuel is used only during the marketing of the produce. The production of organic and conventional farmers are not mechanized because the respondents are small-scale farmers (**Table 1**). Limiting the system boundary at the farm gate level will eliminate the fuel consumption of the farmers. Hence, the calculated global warming potential is zero based on the system boundary for both organic and conventional production systems.

General Discussion

Environmental degradation is happening and has been accelerating through the years. The continuous depletion of the natural resource base such as air, water and soil, decreasing biodiversity through destruction of its natural habitat and the over-all deterioration of the environment are very alarming. Agricultural production systems contributed to the rapid exploitation of our non-renewable resources. The conventional farming system has played an important role in improving food and fibre productivity but poses threat to our environment due to its high dependency on chemical inputs. The natural farming strategies were replaced by conventional agriculture by eliminating the farmer's cultural practices and innovations as product of their own field experiences through time. However, threats to human health and environment offered farmers limited choices but to eventually practice a more sustainable way of farming their crops through organic agriculture.

The application of the life cycle assessment in identifying the possible environmental burdens of conventional and organic vegetable farming systems is a useful decision-making tool. Farming practices, inputs such as energy, fuel, fertilizers (organic and inorganic) and chemical pesticides were the basis in assessing the potential emissions (GWP, AP, EP and HTP) to the environment.

The conventional vegetable farming has higher emission contribution of GWP and AP than organic vegetable farming (**Table 11**). Also, conventional farming has a threat to human health due to its pesticide application measured as HTP at 6.51E+03 g 1,4 DCB-eq kg^{-1} of vegetable.

The emissions of organic and conventional vegetable farming per kg of marketable produced showed that global warming potential (GWP) in conventional farming is 43% higher than organic farming. Acidification potential (AP) is 23% higher in conventional vegetable farming. Conventional farmers had higher fuel consumption during marketing of the produce thus resulting to higher AP and GWP. In eutrophication, the organic vegetable production system appears to contribute 16% higher EP (3.03E+00 kg PO_4-eq kg^{-1}) than the conventional with only 4.70E-01 kg PO_4-eq kg^{-1}. This value is based on the assumption that in the organic production system, available N and P in the soil after crop uptake are all subject to runoff to bodies of water which cause eutrophication. Although organic farmers farm, and hence high residual N and P, these nutrients are in bounded forms in the organic matter and are not readily transportable.

These environmental impacts, though less in quantity will be accumulated in different sinks (air, water and soil). Eutrophication will further affect water bodies and extensive application of chemical fertilizers will permanently destroy

Table 11. Environmental impacts of conventional and organic vegetable farming system kg^{-1} of vegetables in Tayabas Quezon, Philippines, 2015.

Variables	Units	Organic		Conventional	
		Value	%Change	Value	%Change
GWP	kg CO_2-eq kg^{-1}	1.21E-01	57%	2.12E-01	100%
AP	g SO_2-eq kg^{-1}	1.06E-03	77%	4.76E-03	100%
EP	kg PO_4-eq kg^{-1}	3.03E+00	100%	4.70E-01	84%
HTP	g 1,4 DCB-eq kg^{-1}			6.51E+03	100%

GWP= Global Warming Potential, AP= Acidification potential,
EP= Eutrophication Potential, HTP= Human Toxicity Potential

applied high amounts of vermicompost and animal manure in their the living soil. Spraying of harmful and banned chemical pesticides destroys the balanced ecosystem biodiversity.

The use of diesel fuel, applications of synthetic chemical fertilizers and higher amount of chemical pesticides contribute to higher emissions of CO_2, SO_2, PO_4 and HTP. Interventions to reduce their uses are important considerations if we are to reduce GHG emissions. Sensitivity analysis shows that 30% reduction of pesticide application will also reduce the amount of human toxicity potential, thus reduction of long term impacts to human health and to the environment. Reduced use of chemical pesticides in conventional farming is one possible improvement to minimize emissions. Farmers can use disease resistant varieties and intensive crop monitoring to prevent pest build-up. Also alternative pest management (APM) which rely on the natural ecological balance by redesigning the agro ecosystem is an effective pest control rather than the use of toxic chemicals (*Zamora et al 2006*). The reduction of diesel fuel during marketing of the produce can also reduce CO_2 emissions and it can be done by developing local markets or careful planning on how to synchronize the marketing of the produce.

Synthetic fertilizer application can be reduced by practicing more ecologically sound appropriate technologies such as crop rotation, green manuring, and multiple cropping. Application of organic manure and vermicompost can also contribute higher eutrophication potential. It has been suggested that to be able meet crop's demand of N, at the same time avoiding heavy P input, the practice of planting leguminous crops and choosing high N and low P content organic fertilizer is important to organic agriculture (*Xi et al 2014*). It should be noted that the present study shows that the soil of Tayabas has high nitrogen content. Thus, application of synthetic N fertilizers can negatively affect the soil in the long run by disrupting the natural balance within the soil. Also, synthetic fertilizer application increases the farming expenses of the farmers resulting to low benefit from crop production.

CONCLUSION

An assessment of the contribution of the current agriculture production systems to environmental degradation is important to identify appropriate solutions. The life cycle analysis (LCA) is a valuable tool to assess which agricultural system contributes higher environmental impact. The LCA evaluates the inputs and outputs of both conventional and organic vegetable production systems in a defined system boundary. Decision on the system boundary, functional units and impact categories is important especially when doing a comparative analysis because the outcome of the assessment is affected by these factors.

This study focused on comparing which agricultural system performs better on different impact categories. It was clearly shown that the conventional vegetable production system's extensive use of chemicals has higher CO^2 and SO_2 contributions than organic farming. Also the use of chemical pesticides increases human toxicity potential which poses higher risks to human health and the environment. There is need for conventional vegetable farmers to shift to a more sustainable production system by reducing the use of external inputs e.g. chemical fertilizers and pesticides, increasing farm diversity to reduce pest infestation and optimizing the resources within the farm.

Organic farming appears to have higher potential contribution to eutrophication thus, other ecologically sound farming practices in improving soil fertility should be considered. This study can increase awareness; develop appropriate technologies and innovate, and guide decision makers on improving the food production system whilst reducing environmental impacts.

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