

Model Simulations of a Mesocosm Experiment Investigating Environmental Risk Assessment of Floating Gardens in Inle Lake, Myanmar

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Abstract

Agricultural activities on the floating gardens are likely the main source for the contamination that appears to impact the Inle lake ecosystem. This study investigated the nutrient accumulations in water and the pesticide residues from water, sediment, tomato fruits as affected by Good Agricultural Practices (GAP) and non-GAP on floating beds (hydroponic cultivation techniques) grown in the mesocosm. This trial was conducted at Yezin Agricultural University (Phyu campus), Myanmar during the wet season of 2020. All data were analyzed using Student's t-test. The results found that total nitrogen, phosphorus, potassium and organic carbon in water were greater accumulated in non-GAP than GAP. The water quality index showed that non-GAP was threatened to the water body. In tomato fruit, four residual pesticides were detected in non-GAP while only one was found in GAP. The residual detection of pesticide in the surface water and sediment showed that the non-GAP farm had higher degree and amount of pesticide residues than the GAP areas. This indicated that poor management of fertilizers and pesticides usage has had a negative effect on the environments. It could be concluded that GAP was environmentally friendly, but non-GAP was intended more impact on environment. Environmental risk assessment implies establishing a management strategy that aims at reducing or minimizing the impact of agrochemicals under agricultural production.

Keywords: Floating garden; Nutrient; Pesticide residue; Water quality index

1. Introduction

Nonpoint source pollution from agriculture is the major source of pollution (Letson *et al.*, 1993). The major pollution of agriculture comes from leaching of animal waste and nutrients runoff from agricultural land. As Taylor *et al.* (1992) point out, the potential sources of environmental externalities from agricultural production activities are (1) fertilizers and pesticides percolating into groundwater; (2) fertilizers and pesticides in surface runoff; (3) volatilization losses of fertilizers at the time of application; and (4) soil erosion resulting in sediment deposition off the field.

Nutrients, primarily nitrogen (N), phosphorus (P), and potassium (K), are mainly used to agricultural crops as nutrients to encourage growth. Too much amount of nutrients in excess of uptake by crops caused the possible source of pollution to underground as well as surface water. Numerous chemical compounds such as pesticides, destroy the growth of different organisms. These compounds are potential contaminants for both ground and surface waters (Libby and Boggess, 1990). An extensive environmental assessments express that the higher amount of nutrients effects on

the quality of water, causing eutrophication, deposition of acids, production of natural and ecosystem management, and the ozone depletion by means of nitrous oxide which appears in the reaction of nitrogen cycle (USEPA, 1989). Therefore, agricultural problems are a very important part of overall environmental and resource issues.

Tomato (*Lycopersicon esculentum* Mill.) is an essential and high-value vegetable crop that is commonly grown worldwide (Naika *et al.*, 2005) with the production of 188 million tons in 2018 (FAO, 2018). Tomato cultivated areas in Myanmar is about 104,000 hectares with the production of 1.2 million tons and the average yield is 11,500 kg per hectare in 2018 (CSO, 2018). Tomato is cultivated around the country with two types such as upland and lowland. Lowland tomato is grown using the floating bed, mainly in Inle Lake.

Good Agricultural Practices (GAP) systems, quality systems, are applied in order to sustain best practices for agricultural production, sustainable agricultural production systems with environmentally and economically friendly (Dankers, 2003; Igarashi, 2004). Good management practices for agriculture in Inle Lake need to be identified and monitored in order to reduce the impacts of floating gardens on the sustainability of ecosystem. Therefore, this study examines to environmental risk assessment of floating garden to evaluate nutrient loads into water, and to investigate the pesticide residues from water, sediment and tomato fruit as affected by GAP and non-GAP of tomato grown on the floating beds.

2. Materials and Methods

2.1 Experimental site

The experiment was conducted at Yezin Agricultural University (Phyu campus), Bago region, Myanmar growing period from August to December, 2020. This area has a humid subtropical climate with three seasons: summer season (March - June), rainy season (July - October), and winter season (November-February). Daily humidity is approximately 80% and the average temperature is 21°C to 39 °C during the rainy season.

2.2 Experimental design and treatment

This study was designated with floating beds used in the pot under the net-house condition. Two types of agricultural practice were used as good agricultural practices (GAP) and non-good agricultural practices (non-GAP) with five replications (Figure 1). The tested tomato variety was (F₁-hybrid) with 140 days of crop duration. Tomato seeds were grown in seed tray of soil with the addition of well decomposed compost (3:1 by v/v). Uniform, healthy and 30 day-old tomato seedlings were transplanted in each pot. The diameter of pot size was 100 cm and four plants were grown in each pot with the spacing of 60 x 60 cm between rows and within plants. The cultivation activities such as weeding by hand, staking by bamboo poles, irrigation were done as farmers' management practices of each treatment. These agricultural practices were followed as the farmers who cultivated tomato on floating gardens in Inle Lake, Myanmar. Fertilizer and pesticide applications for GAP and non-GAP tomato cultivation on floating beds in pot experiment are presented in Table 1.

2.3 Water sampling and analyses

Water samples were collected from GAP and non-GAP areas after the harvesting tomato fruits. Water was measured in situ from both areas for the following parameters; temperature, pH, electrical conductivity and dissolved oxygen (DO) using a HACH HQ40d Portable meter (HACH, 2017). Water samples were kept in 1 liter bottles to determine alkalinity, total hardness, biochemical oxygen demand (BOD), chemical oxygen demand (COD) and nutrient analyses. Samples were stored in a cool ice box, and transported from the field to the laboratory at constant temperature of 4 - 6 °C until analysis. Total alkalinity was measured by titration method (Hydrology Project- Technical Assistance, 1999). Total hardness was calculated by using the concentration of calcium (Ca²⁺), and magnesium (Mg²⁺) according to (Clesceri *et al.*, 1998). BOD and COD were measured by BOD measurement system-BD 600 and COD measurement system-MD 200,

respectively (Clesceri *et al.*, 1998). The concentrations of nitrate ion (NO₃⁻), ortho-P, total phosphorus (P) and potassium (K⁺) were analyzed by using a continuous flow analyzer (Skalar Analytical, 1993). Total nitrogen (N)

was analyzed by Kjeldahl distillation method (Estefan *et al.*, 2013). The samples were analyzed at the laboratory of the Department of Soil and Water Science, Yezin Agricultural University, Myanmar.



Figure 1. Pot experiment

Table 1. Fertilizer and pesticide applications for GAP and non-GAP tomato cultivation

Description	Unit	Total amount used		Application frequency	
		GAP	non-GAP	GAP	non-GAP
Compound fertilizer (15:15:15)	(kg/ha)	1,670	2,260	10	10
Foliar fertilizer application	(L/ha)	2.36	3.25	5	5
Pesticide application					
Acephate 75% SP	(kg/ha)	0.80	1.0	2	2
Abamectin 1.8%EC	(L/ha)	0.80	1.0	2	2
Lambda-cyhalothrin 10%EC	(L/ha)	0.80	1.0	2	2
Mancozeb 80 %WP	(kg/ha)	0.80	1.2	2	2
Azoxystrobin 20%SC	(L/ha)	0.44	0.6	2	2
Hexaconazole 5%SC	(L/ha)	0.44	0.5	2	2

2.4 Pesticide residues analyses in water, sediment and tomato

Pesticide standards with purity percent 96-99 were purchased from Fluka (Sigma–Aldrich, Steinheim, Germany), pesticide-grade solvents methanol, acetonitrile, and LC- grade water were obtained from Merck (Darmstadt, Germany). Analytical-grade NaCl and MgSO₄ for residual pesticide analysis were purchased from Beihua Fine-Chemicals Co. Ltd and Sinopharm Chemical Reagent Co. Ltd (Beijing, China), respectively. Primary secondary amine, graphitized carbon black and nylon syringe filters (0.22-µm) were purchased from Agela Technologies Inc. (Tengda, Tianjin, PRC). The standard (stock solution) was prepared by using acetonitrile and working standard solutions were prepared by dilution of the corresponding stock solutions in acetonitrile. They were used for spiking of samples in recovery studies and calibration purposes. All reagents and samples were stored at -20 C° until analysis. The pesticide residues were analyzed at the Department of Agriculture, Ministry of Agriculture and Cooperatives, Khon Kaen, Thailand by using liquid chromatography-tandem mass spectrometry (LC-MS/MS) with standard QuEChERS EN 15662 method.

2.5 Water quality index calculation

Water quality index was performed to compare water quality parameters with respective regulatory standards, which gives a single indicator to describe the overall quality of a water body (Boyacioglu, 2010). This method is an effective standard to categorize surface water quality (Sánchez *et al.*, 2007).

Nine physico-chemical parameters; pH, EC, TDS, total alkalinity, total hardness, Ca, Mg, DO, BOD, were used to calculate WQI values by the weighted arithmetic index method according to the following equations (Tyagi *et al.*, 2013).

$$\text{Quality rating (Qi)} = 100((V_n - V_i) / (S_i - V_i)) \quad (1)$$

where, V_n is the concentration of water quality parameter; V_i is the ideal value of ith parameter in pure water. In most cases, V_i was 0 and pH, DO was 7 and 14.6, respectively;

Relative weight (W_i) was calculated according to the following equation.

$$W_i = K/S_i \quad (2)$$

where, K is constant for proportionality; S_i is the recommended standard value for ith parameter (WHO, 2008). The overall water quality index was calculated with the following equation (Tyagi *et al.*, 2013).

$$WQI = \sum (Q_i) W_i / \sum W_i \quad (3)$$

Water quality was classified by the WQI ranges from 0 to 100; (1) WQI values of 0 - 25 is excellent water quality, (2) 25 - 50 is good water quality, (3) 50 - 75 and (4) 75 - 100 indicate poor and very poor water quality, respectively (Tyagi *et al.*, 2013).

2.6 Statistical analysis

In this study, Student's t-test was performed to evaluate the comparisons between GAP and non-GAP practices about tomato yield, yield characters and chemical and physical properties of water and sediment. All data were done by using Statistix 10 and Excel program (2016).

3. Results and Discussion

3.1 Water quality parameters

The physical and chemical parameters as affected by different agricultural practices of tomato cultivation on the floating bed are presented in Table (2). In this study, the t-test showed that there was no significant difference in pH level between two agricultural practices. It was 6.52 and 6.43 for GAP and non-GAP, respectively. The pH level is good for both practices, indicating that these values might have an increase in the movement of nutrients in the water body.

Table 2. Physical and chemical parameters of water quality as affected by different agricultural practices of tomato cultivation

Characteristics	Unit	GAP		non-GAP		<i>p</i> -value
		Mean	SD	Mean	SD	
pH	-	6.52	0.11	6.43	0.26	0.231
EC	(dS/m)	0.48	0.15	0.79	0.13	0.003
Ca ²⁺	(mg/L)	25.19	2.08	24.50	2.96	0.342
Mg ²⁺	(mg/L)	16.62	3.35	17.69	3.76	0.324
TDS	(mg/L)	351.60	44.94	431.00	77.84	0.042
TSS	(mg/L)	545.60	96.62	748.20	138.55	0.014
Total Alkalinity	(mg/L)	6.44	0.73	7.18	0.96	0.103
Total Hardness	(mg/L)	126.04	22.70	147.22	20.22	0.378
Total Nitrogen	(mg/L)	10.72	2.32	15.23	1.46	0.003
NO ₃ ⁻	(mg/L)	0.20	0.04	0.25	0.06	0.115
Total phosphorus	(mg/L)	11.47	3.36	16.95	5.47	0.046
ortho-P	(mg/L)	10.37	3.11	15.40	3.98	0.028
Total potassium	(mg/L)	16.26	4.01	22.88	7.00	0.034
BOD	(mg/L)	2.79	0.88	4.69	0.50	0.001
COD	(mg/L)	41.85	8.43	72.02	9.00	0.000
DO	(mg/L)	7.04	1.23	4.67	0.66	0.003

EC = electrical conductivity; TDS = total dissolved solid; TSS = total suspended solid;
BOD = biological oxygen demand; COD = chemical oxygen demand; DO = Dissolved oxygen

Electrical conductivity (EC) is a further common measurement used to evaluate water quality and is directly associated to the total dissolved inorganic substances in the water. The t-test showed there were significant differences in EC level between two agricultural practices ($P = 0.003$). It was noted that both practices showed low EC values, but it was lower in the GAP (0.48 dS/m) when compared with non-GAP (0.79 dS/m). The reduction in water EC value was observed in both practices when compared to the initial water values (1.55 dS/m).

Calcium is one of the main inorganic cation as Ca²⁺ ions (dissociation of calcium chloride or calcium sulphate) in saltwater and freshwater. This study found that Ca²⁺ concentration in water were not significant different between two practices. It was 25.19 and 24.50 mg/L for GAP and non-GAP, respectively. Magnesium is commonly found in natural water as Mg²⁺, a crucial element for living organisms found in organic matter and in various organometallic compounds. In this study, Mg²⁺ concentration was not significant different between two practices. It was 16.62 and 17.69 mg/L for GAP and non-GAP, respectively.

In this study, the t-test results showed that significant difference was observed in TDS between two agricultural practices ($P = 0.042$). The TDS value was higher in the non-GAP (431.00 mg/L) when compared with GAP (351.60 mg/L). Total suspended solids (TSS) are sediments, organic residues, and other solid materials which are suspended in the water body. The results showed that there was significant difference in TSS between GAP and non-GAP practices ($P = 0.014$). TSS value was lower in the GAP (545.60 mg/L) when compared with non-GAP (748.20 mg/L). High concentration of TSS might come from the floating bed such as organic materials. Hence, it can be a transporter for nutrients and pesticides.

Alkalinity is an indicator of acid-neutralization capacity of natural waters. Carbonates, bicarbonates, and hydroxides are common components of alkalinity. Alkalinity is important for aquatic system because it buffers pH changes. Carbonate and bicarbonate combine with some heavy metals and reduce their toxicity (USEPA, 1986). In this study, total alkalinity in water did not vary between the two practices. The total alkalinity is very low (6.44 mg/L in GAP

and 7.18mg/L in non-GAP) when compared with the initial measurement (716). This result might be due to the present of low content of carbonate (CO_3^{2-}) (USEPA, 1986). There was no significant difference in total hardness between two practices. The degree of water hardness was 126.04 mg/L in GAP and 147.22 mg/L in non-GAP. Higher values of total hardness in this study may be due to increasing Ca and Mg.

The t-test showed that there was significant difference in total N content in water between two practices ($P = 0.003$). Total N content of GAP (10.72 mg/L) was lower than that of non-GAP (15.23 mg/L). It was found that nitrogen content tended to increase with the increasing use of fertilizers in non-GAP practices when compared with GAP practice. Nitrate is soluble and mobile in water and is the form of nitrogen which causes water quality problems. Therefore, nitrate can readily move with water and can leach through the soil to groundwater. In this study, there was no significant difference in NO_3^- concentration between two agricultural practices. However, the NO_3^- concentration (0.20 mg/L) was found a lower in the GAP when compared with the non-GAP (0.25 mg/L). Of particular concern is nitrogen fertilizers that can be converted into nitrates which have an undesirable effect on the environment (Libby and Boggess, 1990).

The t-test result indicated that there were significant differences in total phosphorus and ortho-P content concentrations between the two agricultural practices ($P = 0.046$ and $P = 0.028$, respectively). In comparing two agricultural practices, total phosphorus (16.95 mg/L) and ortho-P (15.40 mg/L) in non-GAP were higher than in GAP (11.47 and 10.37 mg/L, respectively). In this study, there was significant difference in K^+ concentration between the two agricultural practices ($P = 0.034$). The K^+ concentration was found a higher in the non-GAP (22.88 mg/L) than GAP (16.26 mg/L). It indicated that K is discharging from the tomato cultivation.

Table 2 presents BOD, COD and DO concentrations in water as affected by different agricultural practices of tomato cultivation. In this study, there was significant difference in BOD in water between the two practices ($P = 0.001$). The BOD concentration was

lower in the GAP (2.79 mg/L) when compared with non-GAP (4.69 mg/L). The greater the BOD concentration in non-GAP might be due to more application of chemical fertilizers. Increase in BOD indicates the greater amount of organic matters available for oxygen consuming bacteria and resulted in oxygen depletion and lowering dissolved oxygen (DO), this reflects aquatic organisms lead to stress, suffocate and die (Almeida *et al.*, 2008). Chemical oxygen demand (COD) measures the amount of oxygen needed to chemically oxidize all organic and inorganic compounds in the water (TCEQ, 2014). The result of this study found that there was a highly significant difference in COD between two practices ($P = 0.00$). The COD concentration was lower in the GAP (41.85 mg/L) when compared with non-GAP (72.02 mg/L). COD concentration may be controlled by a primary production of plant matter and decomposition rates (Mostofa *et al.*, 2013). In this study, there was significant difference in DO between two practices. DO concentration was 7.04 and 4.67mg/L in GAP and non-GAP, respectively. The DO conditions might have been caused by higher organic load (Kuruppu, 2016).

3.2 Water quality index (WQI)

The WQI value of this study is presented in Figure 2. The WQI value showed a lower in GAP (58.49) than non-GAP (82.24). The water quality of both practices was affected by pollution. The water quality was poor condition in GAP, while it was very poor in non-GAP. This might probably be due to the excessive usage of fertilizers in tomato cultivation.

3.3 Pesticide residue in water, sediment and tomato fruit

Figure 3 shows the mean concentration of pesticide residues in tomato fruit as affected by different agricultural practices of tomato cultivation in the floating media in pot in 2020. Regarding to the analysis of tomato fruit samples, four pesticides were detected in non-GAP while only one was found in GAP. In non-GAP, cypermethrin was detected with the amount of 12 $\mu\text{g}/\text{kg}$ which is less than the

maximum residue level (200 µg/kg) (WHO 2021). The result might be no risk to human health, but long-term exposure can cause health risks. It was followed by thiamethoxam

with the amount of 5.05 µg/kg, carbofuran (1.55 µg/kg) and L-cyhalothrin ((1.1 µg/kg). In GAP, only thiamethoxam was detected with the amount of 3.8 µg/kg.

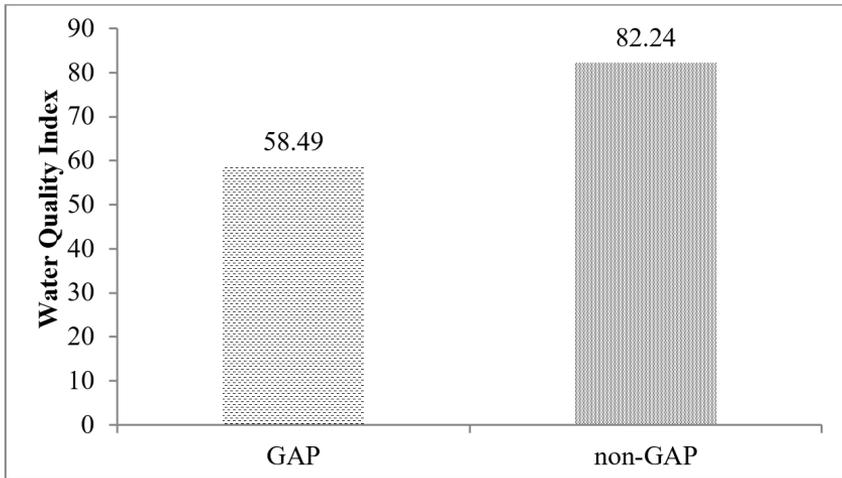


Figure 2. Water quality index (WQI) as affected by different agricultural practices of tomato cultivation

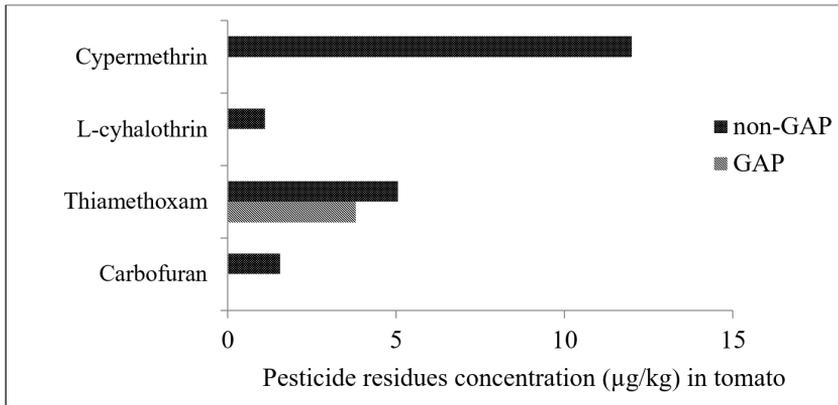


Figure 3. Mean concentrations of pesticide residues in tomato fruit as affected by different agricultural practices of tomato cultivation

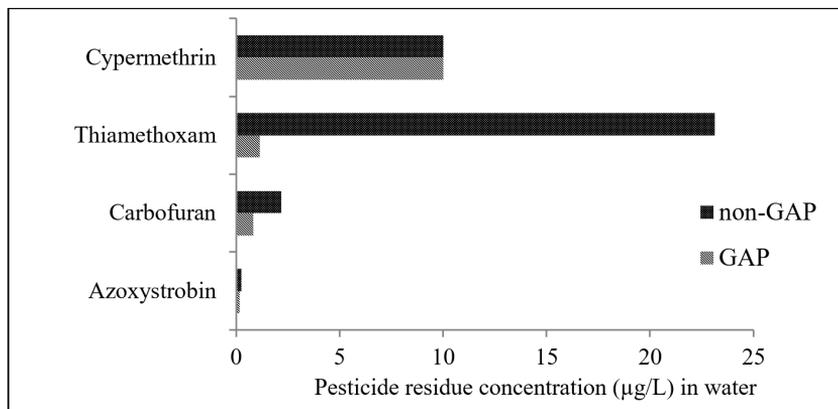


Figure 4. Mean concentrations of pesticide residues in water as affected by different agricultural practices of tomato cultivation

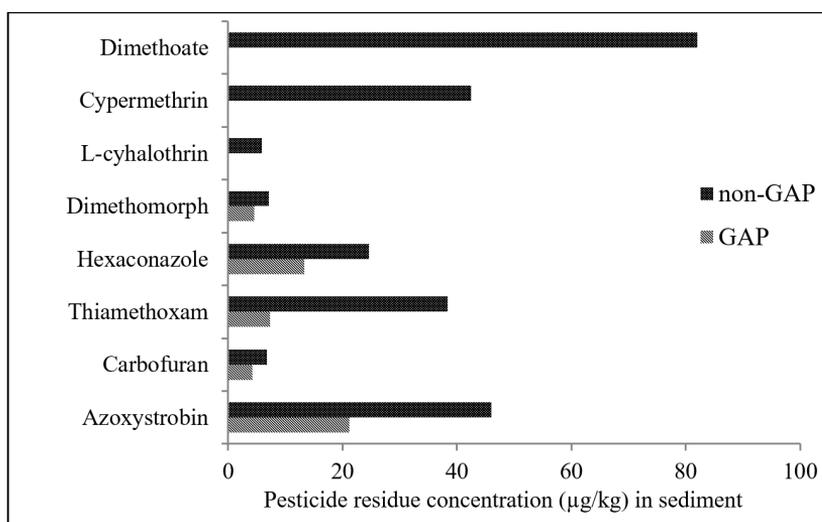


Figure 5. Mean concentrations of pesticide residue in sediment as affected by different agricultural practices of tomato cultivation

Regarding to the analysis of water samples, four pesticides were detected in GAP and non-GAP (Figure 4). In GAP, cypermethrin was detected with the highest concentration of 10 µg/L which was followed by thiamethoxam (1.14 µg/L), carbofuran (0.83 µg/L) and azoxystrobin (0.18 µg/L). In non-GAP, thiamethoxam was detected with the highest concentration of 23.14 µg/L which was followed by cypermethrin (10 µg/L), carbofuran (2.14 µg/L) and azoxystrobin (0.25 µg/L).

Regarding to the analysis of sediment samples, five pesticides were detected in GAP while eight was found in non-GAP (Figure 5). In GAP, azoxystrobin was found with the level of 21 µg/kg, which was followed by hexaconazole (13 µg/kg), thiamethoxam (7 µg/kg), dimethomorph (5 µg/kg) and carbofuran (4.3 µg/kg). In non-GAP, dimethoate was detected with the highest concentration of 82 µg/kg which was followed by azoxystrobin (46 µg/kg), cypermethrin (42.5 µg/kg), thiamethoxam (38.4 µg/kg), hexaconazole (24.7 µg/kg), dimethomorph (7.1 µg/kg), carbofuran (6.8 µg/kg) and L-cyhalothrin ((5.9 µg/kg).

4. Conclusion

This study attempted to examine the nutrient accumulation in water and pesticide residues from water, sediment and tomato.

Agricultural practices significantly influence on water quality parameters, particularly total nitrogen, phosphorus and potassium accumulation. In comparing the nutrients concentrations in water, non-GAP was higher contaminated than GAP. It could be concluded that GAP was environmentally friendly, but non-GAP was intended more impact on environment. The more potentially input of nutrients for cultivation, the more nutrients deposition in the water. The result found that pollution between the two agricultural practices, non-GAP has the highest water quality index indicating that the water quality in non-GAP was a very poor condition, probably be due to the excessive usage of fertilizers. In tomato fruit, four pesticides were detected in non-GAP while only one was found in GAP. The residual pesticides showed that the non-GAP farm had higher quantity of pesticide residues than the GAP areas. It could be concluded that the extensive use of chemical fertilizers and pesticides to increase agricultural production could be a significant source of pollution to the water body. Therefore, there would need to manage pollution sources in order to protect ecology of the lake by doing management of soil and water. This study revealed that GAP production gives an idea on the positive effects in order to reduce the impacts of floating gardens on the sustainability of lake environment and to improve the livelihoods of the peoples.

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