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Environmental Sustainability and Food Safety of the Practice of Urban Agriculture in Great Bandung

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ABSTRACT

Urban farming activities is markedly increasing with expectation to strengthen the food security in the cities, however, the crop safety and the environmental sustainability of farming activities is questioned. To address environmental sustainability, examination of river water quality and pesticide residue both in the water and crop production in peri-urban areas of Great Bandung were carried out. STORET index were used to identify the quality of water source with reference to Indonesia Ministry of Environment as well as the biodiversity index to ensure the health of aquatic ecosystem. The results showed that the urban farming practices had utilized clean and uncontaminated water sources to irrigate the land. The good quality of water sources could be maintained even after urban farming activities. The diversity of plankton and macrozoobenthos were relatively increasing, with low-medium level of diversity (H' index = 0.3 – 2.9), even in the downstream areas after farming land. None of pesticide residues were found in the crop products. The crops from peri-urban farming of the Great Bandung were safely consumed. Meanwhile, the sustainability of urban farming in the peripheral areas of Great Bandung might be lasted so far as the upstream river pollution from the city could be well-maintained.

1. INTRODUCTION

One of the global challenges in the 21st century is food production to meet the human needs. According to World Bank [1], human population is expected to increase up to more than 10 million by 2050 and mostly will reside in the cities. To meet the needs of food and nutrition, crop production is expected to increase by 75% in the future. Thus, urban farming is considered to be a solution for global food security and sovereignty. Urban farming is defined as the practice of growing, processing and distributing agricultural products intensively in or around urban areas [2]. Sustainable urban farming might overcome the problem of food security by integrating environmental health, economic benefits and social welfare [3] so that access to food commodities and economy are increasing without damaging the quality of environment [4]. Urban farming potentially supports environmental health by using efficient input of water resources and the use of fertilizers and pesticides in proper amount. The economic benefits of urban farming are derived from cutting off operational costs from producers to consumers. Meanwhile, social welfare can be obtained from the opportunity for social interaction and recreational value in the practice of urban farming.

One of the challenges of urban farming is higher levels of pollution in urban areas compared to rural areas so that it can affect agricultural processes and commodities. Water, soil and air are the main inputs in agricultural practices. Potential pollution that occurs in urban areas might come from industrial activities, domestic waste from residential areas, transportation emissions and other sources of pollution related to human activities in the city. In consequence, it will negatively affect environmental quality in urban areas and failure urban farming practices and its commodities [5, 6].

Generally, agricultural activities in urban areas utilize limited land; from vertical gardens, rooftop gardens even house garden or yard. Urban farming mostly planted perishable crops, such as leafy plants (vegetables) and fruits which are also susceptible to air pollutants deposition [7, 8]. In addition, urban farming practices occasionally reuse wastewater as a water source to irrigate agricultural land. The high content of nutrients, especially nitrates and phosphates, in wastewater helps plant fertility so that it can cut costs for buying fertilizers or pesticides. On the other hand, untreated wastewater may contain hazardous compounds such as heavy metals and hydrocarbons [6, 9], and contaminated by pathogens [10] that possibly contaminate soil and agricultural commodities and have a risk on human health [6, 9, 11, 12].

Urban farming practices are threatened by excessive use of agricultural chemicals that deposits residues in crops. The use of pesticides in intensive and large-scale agriculture has been shown to contribute to environmental pollution and health. This can happen mainly due to inappropriate use of pesticides or careless handling of pesticides [13]. Thus, the challenge of food security becomes an important issue in agricultural practices in urban areas.

Great Bandung area is the second most populous metropolitan city after Jakarta (Jabodetabek) with a population of 8 million people [14]. For fulfilling demand of vegetables and fruits, the Great Bandung area is supported by agriculture in suburban areas, one is West Bandung Regency. Located on the borderland of Bandung City, West Bandung Regency is leading area for most agricultural activities in Great Bandung with suburban characteristics. Along with suburban development, commercial agriculture has emerged in some peri-urban areas of Great Bandung, one is Lembang District, West Bandung Regency. Geographically, this area has close proximity to the intra-urban area, Bandung City. The peri-urban zone of Great Bandung is an area that run into peri-urbanization phenomenon. The massive development was occurred from city centre to the sub urban as the centre of new urban activities [15].

Several studies have been shown the presence of pesticide residues in both water sources and horticultural crops produced by intensive agriculture in Lembang, Parongpong and Cikidang areas [13, 16, 17]. These studies focus on large-scale intensive agriculture, while research focuses on environmental quality and food safety in small-scale urban farming is still limited. Therefore, this research analyses and evaluates urban farming practices on water quality and tries to ensure food safety by assessing potential pesticide residue on agricultural commodities of urban farming practices. The location includes Cikidang, Cihideung and Lembang villages which are areas with intensive agricultural practices and are the majority of vegetable and fruit supply areas in Great Bandung.

2. MATERIALS AND METHODS

2.1 Study area

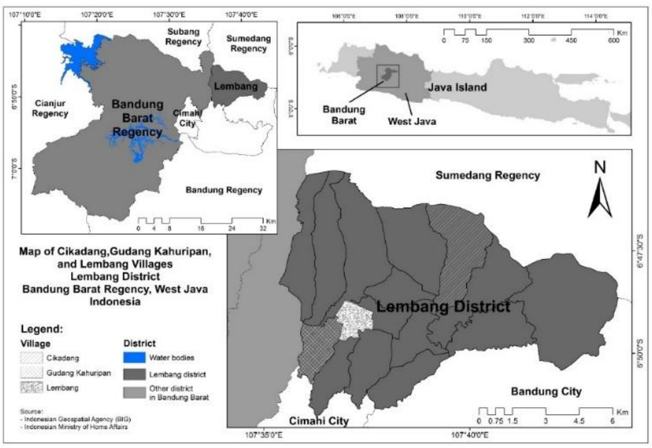

Figure 1. Map of study area

The study was conducted in the basis of commercial urban agriculture in Great Bandung. Three locations were chosen to represent urban farming activities and as the majority of vegetable and fruit supply areas to Great Bandung. Although it is located in the peri-urban zone of Great Bandung, the study area can be categorized as urban agriculture. Urban agriculture does not only include agricultural activities within the urban zone but also includes the peri-urban zone which has direct linkages and interactions with the urban food system [18]. Agricultural practices at the study area go hand in hand with massive development in the surrounding area which is undergoing development and transition to urban areas. The three locations are (see Figure 1):

a. Land around the PPI Complex, Jalan Mutiara 1, Lembang Village, Lembang District. The land area is about 7.3 hectares. The water source for irrigation derived from Situ Umar. Situ Umar is a lake-like located inside a tourist attraction. The farmers create a waterway from tourist attraction to their land.

b. Land in Cisalasih Village, Cikidang Village, Lembang District, West Bandung Regency. The estimated land area of the combined land owned by residents and Perhutani is around 500 hectares. However, each individual farmer owns approximately 0.25 hectares. Water sources come from 3 springs (Citamiya, Legok oray and Mount Geledung Cisalasih).

c. Land in Pasir Wangi Village, Gudang Kahuripan Village, Lembang District, West Bandung Regency. The water sources come from Cihideung River.

2.2 Water quality and aquatic organism analysis

In situ water sampling was designed to cover potential water that flowing to and leaching from urban farming land. The distance between urban farming land and water source was less than 50 meters. The river is a source of water for irrigation as well as a reservoir for leaching and material input from urban farming.

Water sampling protocols refer to standard method as described by APHA [19]. Sampling was carried out twice in the upstream area (before urban farming land) and downstream area (after urban farming land), with an hour time interval. At each sampling point, five samples were collected for physio-chemical, trace metals, pesticide residue and aquatic organism (plankton and macro zoobenthos). Water samples for physico-chemical analysis were collected into 1L high density polyethylene (HDPE) bottles. For metal analysis, water samples were filtered using filtered membrane with 0.45µm pore size and added HNO_3 solution until pH < 2 prior to be stored. Plankton were collected using plankton net. The samples preserved by lugol solution prior to analysis in the laboratory. For macrozoobenthos sampling, grab sampler were used. The samples then sieved to isolate the organism and to separate from sedimen/mud. The sample then stored in the bottle and preserved using formalin 5% for further analysis in the laboratory.

In situ parameters (temperature, DO, alkalinity and conductivity) were measured using portable instrument (thermometer for temperature, DO meter for DO and Lutron Electronic for alkalinity and conductivity). Nitrate and phospate analysis were determined using spectrophotometer technique. TSS was analysed using gravimetri technique. Metal analysis were conducted using Atomic Absorption Spectrophotometry (AAS).

To analyse pesticide residue, 100mL water sample was extracted using organic solvent n-hexane. The sample was shaken for 5 minutes until 2 layer appeared. The water layer was separated and added by n-hexane, then shake. After the layer appeared, the water layer was discarded and n-hexane solution was combined with other n-hexane. The solution then added by 5gr natrium sulphate powder anhydrate until all the water were bounded. The samples then cleaned up and purified until it being concentrated. The measurement of pesticide residue was carried out using Gas Chromatography Mass Spectrophotometry (GC-MS).

In case of aquatic organism, plankton counting were carried out using sedgewick rafter counting chamber under light microscope. Macro zoobenthos were identified and quantified manually using referred species identification book.

Once all parameters were calculated, further analysis were conducted to determine water quality status and diversity index of aquatic organism using following formulas:

$$H' = -\sum[(ni/N) \times \ln(ni/N)] \quad (1)$$

a. STORET index for water quality status

The status of river water quality is evaluated using STORET Index by comparing the water quality data with the standard referred to [20] concerning Water Quality Management and Water Pollution Control (class 3 and class 4 for agricultural purposes). If the value meets the quality standard, then the score is 0, otherwise the score is according to the list in Table 1. Furthermore, the final score of the assessment will show the status of water quality which is categorized into 4 classes:

Class A = very good/meet the quality standard, score 0
Class B = good/lightly polluted, score -1 to -10
Class C = moderate/moderately polluted, score -11 to -30
Class D = bad/severely polluted, score ≥ 31

b. Shannon-Wiener Index for aquatic organism diversity

Table 1. The score of each type of parameter in STORET Index

Number of parameters	Value	Parameters		
		Physical	Chemical	Biology
<10	Max	-1	-2	-3
	Min.	-1	-2	-3
	Means	-3	-6	-9
>10	Max	-2	-4	-6
	Min.	-2	-4	-6
	Means	-6	-12	-18

To determine the diversity of plankton and benthos communities, the following calculation formula is used:

(Ministry of Environment, the Republic of Indonesia No. 115/2003)

where:

H' is Shannon Wiener diversity index and ni is number of individu within same species and N is total number of individu species found

Tabel 2. Criteria for assessing the diversity index of plankton and macrozoobenthos

Diversity Index (H')	Community structure
H' > 3	High diversity
1 < H'< 3	Moderate diversity
H'< 1	Low diversity

Once the diversity index value is obtained, the quality of aquatic environment can be determined according to the criteria listed in Table 2 [21].

2.3 Pesticide residue analysis

To ensure food safety, an assessment was carried out to the vegetables produced from urban farming, including lettuce, green mustard, broccoli and snaps. Pesticide residue on vegetables were analysed using liquid-liquid extraction method, a standard method adopted from The National Pesticide Committee.

Vegetables samples were cut into small pieces and grinded. 25 g of each grinded vegetables were put into Erlenmeyer and homogenized with acetone. The samples were left overnight for static extraction process. 25 mL of the organic phase was taken and put into boiling flask and concentrated by rotavapor in 40°C until its dry. The residue was dissolved using 10mL acetone and ready to be measured by GC/MS with ECD detector.

3. RESULTS AND DISCUSSION

3.1 Water quality status of irrigation water source for urban farming

According to evaluation using STORET index, water source for land irrigation of urban farming was classified as good and very good (based on class 3 and 4 for agricultural purposes) that is listed in Table 3. In terms of water quality, none of pesticide residue parameters were detected in the water sources and almost all parameters meet the quality standard except BOD.

Generally, the waste generated from urban farming were mostly found to be non- hazardous except pesticide waste [22]. Pesticides contain chemicals that can persist in the environment and are difficult to break down or take a long time to decompose. These chemicals can accumulate in the food chain and spread over a wide range. One of the hazardous chemicals is organochlorine which can have a negative impact on human health and the environment. According to water quality analysis, pesticide residue especially lindane and methoxychlor were not detected in the water source used for urban farming as well as leached to the water sources. Lindane and Methoxychlor are organochlorine (OC) pesticide that were classified as persistent organic pollutant (POP) and their use was already prohibited worldwide. However, some farmers still use for its lower operational cost and effectiveness. Although there was no OC detected in the water source of the study area, there is still potentially OC pollutant in the future since some farmers in the upper Citarum watershed were reported still using the OC pesticides [23].

Ministry of Environment, the Republic of Indonesia set BOD value for class 3 and 4 of 6 mg/L and 12 mg/L, respectively. Downstream water sources of urban farming land in Cikidang and Lembang village have exceeded BOD quality standard, with the value of 15.5 mg/L and 8.2 mg/L respectively. Meanwhile, the water sources that flowing to and leaching from urban farming land in Cihideung Village had BOD value beyond the applicable standard (Table 4). Although BOD was detected in higher value than the standard applied, the water sources quality was adequate for land irrigation.

Table 3. Water quality status of rivers as water sources for urban farming in Great Bandung based on STORET Index

Class criteria	Cikidang			Cihideung			Lembang		
	Score	Status	Parameters exceeded the standard	Score	Status	Parameters exceeded the standard	Score	Status	Parameters exceeded the standard
Class 3	0	Very good	–	-10	Good	BOD	-8	Good	BOD
Class 4	0	Very good	–	-10	Good	BOD	0	Very good	–

Table 4. Water quality characteristics of rivers as water sources for urban farming in Great Bandung

No.	Parameters	Unit	STATION*					
			Cikidang 1	Cikidang 2	Cihideung 1	Cihideung 2	Lembang 1	Lembang 2
1	Temperature	^{0}C	21	22	23,5	22	24	29
2	Conductivity	µmhos/cm	57	92	455	453	541	659
3	Total Suspended Solid (TSS)	mg/L	1.2	59	88	42	15	44
4	BOD	mg/L	1.7	6	36	15.5	5.1	8.2
5	Dissolved Oxygen	mg/L	6.5	6.7	6.2	6.1	1.8	2.7
6	pH	–	7.01	7.24	7.59	7.59	7.26	7.18
7	Lead (Pb)	mg/L	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006	< 0.006
8	Cadmium (Cd)	mg/L	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
9	Nitrate (NO_3-N)	mg/L	0.622	0.487	0.697	1.306	0.209	0.389
10	Total Phosphate (PO_4-P)	mg/L	0.148	0.132	0.036	0.036	0.065	0,1.4
11	Lindane	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4
12	Methoxychlor	µg/L	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3	< 0.3

*Note: Number 1 and 2 refer to the upstream and the downstream area respectively in reference with the location of farming land

The BOD value is an indirect indicator that can determine the health of waters and the ability of aquatic ecosystems to support biological life. BOD value fluctuations in waters may occur due to spatial and temporal variations. Increased levels of BOD in water sources flowing from the urban farming land indicate an increase in organic matter content which might derived from domestic waste, sewage and agricultural runoff and livestock activities around the river. Urban farming practice in Cikidang and Lembang village might contribute to leach organic matter to the water. Conversely, organic matter in downstream water source had decreasing after urban farming land in Cihideung Village, showing water quality improvement. Environmentally friendly urban farming practices have been proven to improve the quality of environment by decreasing stormwater runoff [24].

The trend of increasing BOD levels is in line with the increase of TSS levels in the downstream of urban farming land in Cikidang Village and Lembang Village. High levels of TSS indicated great amount of the sediment content (clay, mud, organic matter, etc.) in the river. It can be derived mainly from runoff or other activities in urban areas. Sediment input from soil runoff might be exacerbated especially during rainy season with high precipitation. Globally, most of river pollution comes from anthropogenic activities due to urbanization and intensive agricultural and livestock activities [25]. Overall, the water source used to irrigate urban farming land at the study area was suitable and relatively safe for agricultural activities.

Determining the condition and status of the river as a source for land irrigation of urban farming activities is very important. In some urban farming activities, contamination may happen due to the use of poor quality of water sources. Wastewater use for land irrigation is one of examples. Wastewater commonly contain high nutrients that beneficial for agriculture. Farmers only need few amounts of fertilizers and they may get greater profits. The use of wastewater can conserve water, recycle nutrients and can reduce the use of fertilizers [26]. Although the use of wastewater has a positive impact on crop yields and can minimize production costs, the risks is also come up in relation to food safety. The use of unclean water can cause contamination, either directly or indirectly. Contamination can occur directly when farmers come into contact with unclean water sources that contain pathogenic microorganisms. As a result, health risk from contamination is inevitably [8, 12]. Meanwhile, indirect contamination can occur through the crop yield consumed [11].

3.2 Urban farming impact on aquatic organism

According to diversity index value, plankton and macrozoobenthos in the rivers around study area were classified as low to moderate level of diversity. However, urban farming practices carried out in Cikidang, Cihideung, and Lembang have shown a positive response to the quality of the river. It is indicated by an increase in the diversity of plankton and macrozoobenthos in the downstream after urban farming land (see Figure 2 and Figure 3).

In many studies, urban farming has been shown to increase biodiversity and ecosystem services [27–30]. The increase in the diversity of plankton and macro zoobenthos observed in this study indicates a healthy and adequate aquatic environment for the growth of aquatic organisms. Physical and chemical factors of waters have an important influence on the condition and health of plankton, both in number and diversity. In line with the water quality status, the unpolluted waters around the urban farming land have stimulated an increase in the diversity of plankton and macro zoobenthos. Healthy waters are characterized by the availability of sufficient nutrients and low levels of contamination that support the growth of plankton and benthos.

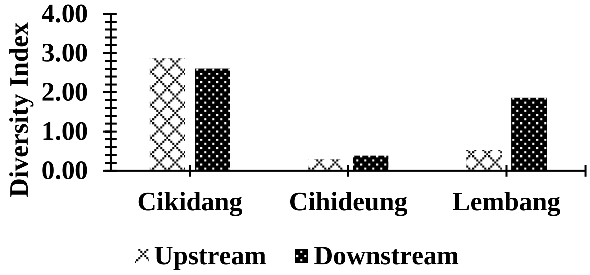

Figure 2. Shannon-Wiener diversity index for plankton both in the upstream and the downstream part of the water sources of urban farming

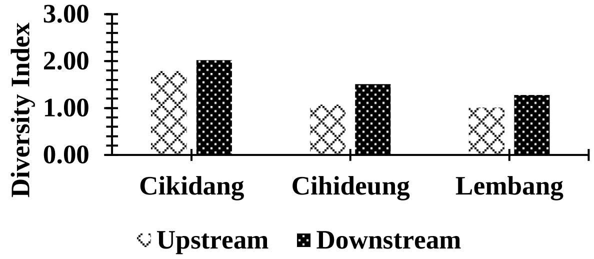

Figure 3. Shannon-Wiener diversity index for macro zoobenthos both in the upstream and the downstream part of the water sources of urban farming

Table 5. Pesticide residue in vegetables of urban farming in Great Bandung

Parameters	Unit	Agricultural commodities				Detection Limit
		Lettuce	Green mustard	Broccoli	Snaps	
DDD	µg/kg	nd	nd	nd	nd	1.0
DDE	µg/kg	nd	nd	nd	nd	1.0
DDT	µg/kg	nd	nd	nd	nd	2.0
Aldrine	µg/kg	nd	nd	nd	nd	1.0
Dieldrin	µg/kg	nd	nd	nd	nd	1.0
Heptachlor	µg/kg	nd	nd	nd	nd	1.0
Methoxychlor	µg/kg	nd	nd	nd	nd	2.0
Chlordane	µg/kg	nd	nd	nd	nd	1.0

*nd = not detected, the value observed was below detection limit

Agricultural activities potentially affect the water quality due to untreated agriculture waste, or farming practice was conventional. This is exemplified by Rahmawati et al. [23] that showed OC residue (lindane) in carrot and potato had slightly higher in conventional carrot farming compare to organic farming due to synthetic fertilizer and pesticide usage. Excessive use of fertilizers might generate agricultural waste that potentially leaching to the body water and cause eutrophication [31]. The residue of fertilizer that pollutes the aquatic environment can be indicated from the content of nitrate and phosphate. The value for nitrate and total phosphate in the water sources were ranged from 0.036 – 1.306 mg/L. This value is far below the quality standard (total phosphate 1 mg/L (class 3) and 5 mg/L (class 4); nitrate 20 mg/L (class 3 and 4)), thus the nutrient levels in the water sources was not become a limiting factor for plankton and macro zoobenthos growth. Excess nitrate and phosphate content in the water can affect the quality of water bodies, cause algal bloom phenomena and encourage the growth of aquatic plants. As a result, dissolved oxygen consumption will increase and affects the life of aquatic organisms. In addition, pesticide contamination to the water had been reported to have negatively affect reproduction and fertility of aquatic organism. Pesando et al. [32] exemplified methoxychlor contamination had disrupted embryo development of sea urchin and altered intracellular biochemical pathways.

3.3 Urban farming impact on crop production

There was no pesticide residue detected on four types of vegetables in Great Bandung urban farming. All the samples showed the residue value below the detection limit (see Table 5). Pesticide contamination in agricultural commodities mostly come from pesticide spraying directly in soil and crop. Plants can be easily contaminated by pesticides that come from soil, water and air and are deposited on the vegetative and reproductive parts (leaves and fruit). In leafy vegetables, more pesticide residue concentrations were found on the outer surface of the leaf than on the inside. Plants may concentrate pesticide residue through different pathways, such as direct uptake from soil, contamination on fruits and foliage, and deposition from air particles. Studies on the presence of pesticide residues in agricultural commodities, especially vegetables and fruit, are often found on large-scale agricultural land, both in developed and developing countries, especially in cash crop commodities [5, 33].

Lembang district is an area with intensive agriculture practice (Figure 4). There have been many studies documenting the presence of pesticide residue contamination in soil and river water in Lembang area. This may happen because of the intensive use of pesticides to combat the pests. Misuse of agricultural chemicals was reported prone to small-scale farmers, especially in developing countries. Lack of knowledge regarding the rules for appropriate use of chemicals and prioritizing economic interests are the main reasons for the misuse of agricultural chemicals on small-scale farmers [13]. In a previous study, the vegetable plantation area in Cikidang Village, Lembang District was reported had contaminated by cypermethrin derived from poor quality well water as water sources for irrigation [16], although the value is smaller than the maximum residue limit (<100ppb).

Inorganic fertilisers and synthetic pesticides were applied by farmers in urban farming practices at the study area. It is mainly used to protect agricultural commodities from pests, diseases and to improve the quality of crop production. However, the pesticide residue was not detected in the samples of vegetables. This can be caused by several possibilities, such as post-harvest handling and vegetables washing, thus can minimize pesticide residues contained in plants. Rinsing the vegetables in running water can reduce even remove pesticide content in plant because the high level of solubility between the pesticide content and water [34]. It can also possible to rinse accidentally through rainwater. Pesticide residue levels are also effectively reduced when farmers consider the interval between pesticide application and harvest time.

In many cases, urban farming practice cultivate green vegetable commodities. Some of them are frequently consumed raw or without cooking, so it has the potential to cause digestive diseases when the farmers use contaminated water sources.

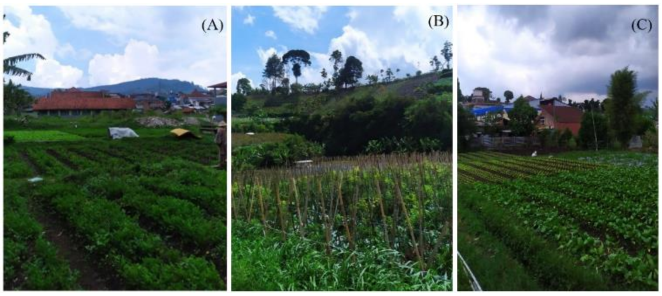

Figure 4. Urban farming practices in: (A) Cihideung, (B) Cikidang and (C) Lembang

In addition, pesticide contamination may occur when edible plant parts are directly exposed to pesticide through spraying. Basically, the use of pesticides has been regulated so that it is supposed to be safely consumed by consumers. The majority of pesticide contamination occurs due to several things, such as: misuse pesticide with inappropriate amount, misused of active ingredients, the use of materials that is not recommended for pesticide composition, and the contamination from the past (farmer used the contaminated land for farming) [12, 35].

The sustainability of urban farming practices was inextricable from the knowledge of urban farming actors (farmers) and proper handling of the use of agricultural chemicals [13, 36]. Farmers with good environmental awareness tend to use clean water sources to irrigate their land. In addition, farmers' knowledge of agricultural management, such as the use of fertilisers in appropriate doses, will minimize pesticide pollution to the environment and pesticide contamination on crop production.

In addition, urban farming activities that are not environmentally friendly can also be a source of pollution for the surrounding aquatic environment. Common sources of pollutants found in aquatic ecosystems from agricultural activities, including urban farming, are pesticides. Pesticide contamination can be found in cultivated agricultural commodities or can directly expose farmers. Direct exposure to pesticides can pose health risks such as dizziness, problems with the respiratory tract and eyes, skin problems and nerve disorders [17, 35].

4. CONCLUSIONS

Urban farming in Great Bandung showed environmentally-safe practice since it utilizes good quality of water sources and it can maintain the water quality so that it can support aquatic organism life. In addition, the vegetables planted are pesticide-free and relatively safe for consumption. One of the challenges to achieve its sustainability is urban pollution which may affect the water source quality in the upstream then will indirectly impact on agricultural practice in the downstream. This is an important consideration to achieve sustainable urban farming practices so that the city's food supply can be fulfilled with concerning food safety. While the results of this study focus on urban farming practices that support environmental sustainability and food security, it also requires a better understanding that urban farming also has an important role in ecosystem services that needs further research.

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