Oregon water quality index comparison (OWQI), overall index of pollutant (OIP) and ecology index in integrated fish farm field

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Abstract. Food security and agriculture sustainability are essential and one of the methods of providing the food needed is the integrated fish farm fields (IFF). This method involves the effective use of land and sustainability to ensure the fulfillment of food needs and the continuous application of this technique. The IFF is expected to reduce the use of fertilizers and fish feed but more chemicals are observed to be applied in the fields. Therefore, this study was conducted to examine the water quality of IFF fields based on the differences in the input and output water using four sampling sites in Samberembe Village, Sleman Regency, Yogyakarta Province. Several tests were conducted in the laboratory for pH, temperature, Total Dissolved Solids (TDS), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD), Total Suspended Solid (TSS) and planktons identification. The results obtained were used to calculate the water quality through Oregon Water Quality Index (OWQI), Overall Index of Pollutant (OIP), ecological or Simpson Dominance Index (D), Shannon Wiener Diversity Index (H'), Evenness Index (E) and Saprobity Index (SI). The values obtained from the calculations include OWQI (87.92, 67.87, 25.52, 25.86), OIP (3.97, 4.48, 4.13, 4.12), SI (2.33, 1.40, 1.40, 1.29), D (0.27, 0.38, 0.24, 0.23), E (0.91, 0.69, 0.81, 0.80), and H` (1.47, 1.43, 1.86, 1.98). It was determined that there is a statistical difference in the chemical parameters between the sample sites since the calculated p-value (0.00) is smaller than the p-value (0.05), suggesting that there is a change in water quality between the sampling locations as a result of IFF. As a result of the change in the SI value, the region became slightly polluted, although this IFF method has a modest impact on the environment.

Key Words: food security, integrated fish farm, plankton, water quality, ecology index.

Introduction. Food security and agriculture sustainability are essential and one of the methods of providing the food needed is the integrated fish farm fields (IFF), which is the combination of fish farm and rice fields. Rice field is very important for the Indonesian people, whose main staple food is rice. This IFF method involves the effective use of land and is categorized to be appropriate when it is sustainable in the social, economic and environmental dimensions (Agyekum-Mensah et al 2012; Brundtland & Khalid 1987). This sustainability makes it possible to fulfill the food quantity and quality required to implement this technology. The method has also been reported by economic studies to be more profitable (Mardjudo & Yasin 2017; Ariska 2020; Mar'I et al 2017; Nurhayati et al 2016; Prasetyo et al 2018). Meanwhile, social studies showed the influence of several variables such as farmers' experience and age in adopting this method (Asaad et al 2018; Septiana et al 2016). The environmental study of the IFF method also showed its ability to alter methane values. This is, however, considered important due to the effect of fertilizer on the environment and the ecology (Mahmudiyah & Soedradjad 2018; Nugroho et al 2017; Rozen et al 2019). Moreover, several studies reported on the technology focus on increasing the production through new methods and experiments, as observed in different fish and rice species (Lantarsih 2016; Rozen et al 2019).

The IFF method is expected to ensure the efficient use and reduction of fertilizers and fish feeds, as reported by several studies (Lestari et al 2019). This is considered necessary due to the contaminants added by these materials to the rice field ecosystem by the excessive use of fertilizers reported to cause pollution (Muhammad et al 2020; Yuttitham 2019) especially in waters (Purbalisa & Mulyadi 2013; Triadiati et al 2012). Moreover, the fish feed has also been reported to be a water pollutant (Paena et al 2017; Sukadi 2010). A study comparing IFF and monoculture fields revealed a decrease in chemical fertilizer use (urea, NPK, and potassium sulfate fertilizer) of 370.4 kg ha^{-1}, but increased organic fertilizer use of 254 kg ha^{-1}, while fish feed use rose by 706 kg ha^{-1} (Syaukat & Julistia 2019).

The contamination of water has the ability to affect the osmosis process in seas and this has further effects on the respiration process, digestion and food absorption of fishes (Anggoro & Subandiyono 2012). Water quality can, however, be determined using parameters such as pH, temperature, Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) (Ferreira et al 2011). All these parameters are combined to a single concept known as Water Quality Indices (WQI) which has been in existence in Germany since 1848 (Abbasi & Abbasi 2012). Oregon Water Quality Index (OWQI) (Cude 2001) and Overall Index of Pollutant (OIP) (Sargaonkar & Deshpande 2003) were used in this study, while biological parameters were applied to indicate pollution and the presence of plankton in the waters used as ecological indicator of pollution (Makkatenni & Juhardi 2020; Sulawesty & Aisyah 2020).

Previous studies have shown the ability of the IFF method to reduce fertilizers and add the fish feed to the field but none has examined how the fish feed is added. There is also a need to study the impact of the IFF methods on the environment, especially on the water quality. Therefore, this research was conducted to examine the water quality of the IFF method through the comparison of the quality in the input, site and output of the IFF fields.

Material and Method

Description of the study sites. The study was conducted in Samberembe Village, Sleman Regency, Yogyakarta Province, in September 2019 during the dry season, as indicated in Figure 1. The study's site was determined by the fact that Sleman Regency, Yogyakarta, was an area with the ability to create IFF and serve as a pilot project for IFF (Syaukat & Julistia 2019). Samberembe Village was one of the pioneering communities in the establishment of IFF. The site Sampling Site 1 (ST1) is located at a latitude of 7°40'12 "S, a longitude of 110°23'49.4" E, and an altitude of 376 m and used the Boyong River as the water source. Water from ST1 flows into the next region to fulfill the water requirements for IFF. Sampling Site 2 (ST2) is situated at latitude 7°40'13.7 "S, longitude 110°23'52" E, height 378 m as an IFF area on the south source water. ST2 accommodates water to fulfill the requirements of rice fields and fish requirements when IFF is sampled in preparation for rice planting. Sampling Site 3 (ST3) is situated on latitude 7°40'17 "S, longitude 110°23'51.6" E, height 368 m and observed to be an IFF rice crop on the north source water. ST3 water is a mixture of water generated from the ST1 flow and a portion of the ST2 water. The IFF condition was planted with rice at the time of sampling. Sampling Site 4 (ST4) is situated on latitude 7°40'16.4 "S, longitude 110°23'50.1" E, and height 369 m and is utilized as the water output.

Data collection. Water samples were obtained from the four sampling locations (ST1, ST2, ST3, and ST4), as mentioned above. These samples were later compared. A sample of 50 mL of plankton was collected by filtering 20.000 mL of water and then it was preserved using 1 mL of 10% formalin solution to be later examined in the laboratory.

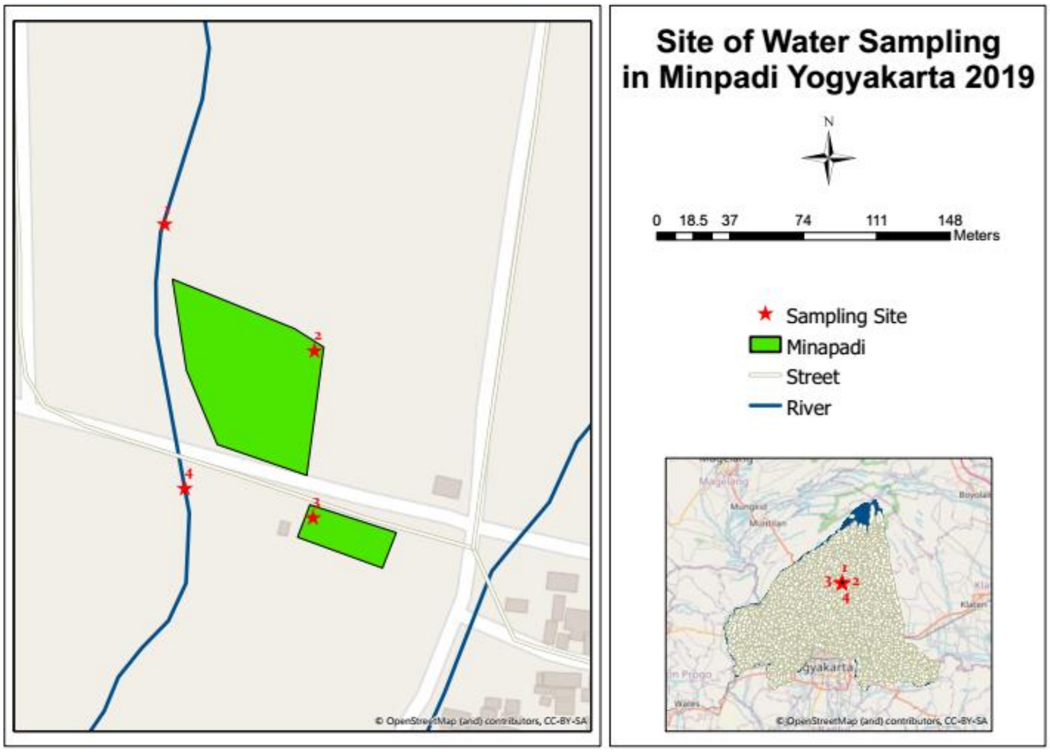

Figure 1. The sampling sites in the integrated fish farm.

Analysis. The planktons were observed in the laboratory using 100x, 200x and 400x magnification microscopes (APHA 1999). The Simpson Dominance Index (D), Shannon Wiener Diversity Index (H') and Evenness Index (E) were used to analyze the phytoplankton in order to study their community structure (Odum & Barrett 2005), which indicates the water quality, based on the Saprobity Index (SI) (Anggoro 1988). The Simpson Dominance Index (D) was calculated using the following equation (Magurran 1988):

$$\mathrm{D} = \sum P_i^{\ 2}$$

Where:
D - Simpson Dominance Index;
pi - $\frac{ni}{N}$;
ni - number of the taxon individuals (i);
N - total number of individuals in the sample.

The Shannon Wiener Diversity Index (H') was calculated using the following equation (Magurran 1988):

$$\mathrm{H}' = -\sum pi \ln pi$$

Where:
H' - Shannon-Wiener Index;
pi - $\frac{ni}{N}$;
ni - number of the taxon individuals (i);
N - total number of individuals in the sample.

The Evenness Index (E) was also calculated based on the following equation (Magurran 1988):

$$E = \frac{H^{`}}{H^{`}_{max}}$$

Where:
E - evenness index;
H’ - Shannon-Wiener Index;
H'max - the maximum possible value of H' which is equivalent to ln s.
s - number of species encountered;

The Saprobity Index (SI) was determined based on the following formula (Dresscher & van der Mark 1976):

$$SI = \frac{1C + 3D - 1B - 3A}{1A + 1B + 1C + 1D}$$

Where:
SI - Saprobity Index;
A – total number of species organism Polysaprobic;
B - total number of species organism α- Mesosaprobic;
C - total number of species organism β- Mesosaprobic;
D - total number of species organism Oligosaprobic.

Water quality was evaluated using OWQI and OIP methods. The five classifications based on OWQI include very poor, poor, fair, good, and excellent. The sub-indices (Si) include temperature, DO, BOD, pH, total solids, ammonia + NO_3-N, total phosphorus and fecal coliform (Abbasi & Abbasi 2012). A higher OWQI value calculated using the following formula indicates a better water quality (Cude 2001):

$$OWQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{S_i^2}}}$$

Where:
n - the number of sub-indices (DO, BOD, pH, total solids, phosphor, total nitrate and temperature);
S_i - the sub-index i.

There are also five water quality classes in OIP as observed in OWQI and these include excellent, acceptable, slightly polluted, polluted and heavily polluted. The pollution index (Pi) used in this formula describes the turbidity, pH, color, % DO, BOD, TDS, hardness, Cl, NO_3, SO_4, As and F (Abbasi & Abbasi 2012). In contrast to OWQI, a lower value of the OIP indicates a good water quality and it can be calculated using the following formula (Sargaonkar & Deshpande 2003):

$$OIP = \frac{\sum_i P_i}{n}$$

Where:
P_i - the pollution index for the $(i)^{th}$ parameter, (i) = 1, 2, ..., n;
n - number of parameters (DO, BOD, pH, total solid, and nitrate).

The data obtained were analyzed using non-parametric statistics, while the results from the four sample sites were compared using the Kruskal Wallis test at a level of significance set at $p<0.05$. Moreover, the statistical analyses were conducted on MINITAB® software version 17.

Results

Water quality index. The chemical parameters determined from the samples are listed in Table 1 and it was found that the values varied across the sampling locations. TDS, TSS, COD, BOD, phosphate, iron, nitrite, and ammonia levels were all different. Between ST1 and ST4, TDS values are all equal to 100, whereas ST2 and ST3 have a lower value. Between ST1 and ST4, there is a rise in nitrate levels. ST1 has the lowest values for TSS, COD, and BOD, whereas ST4 has the lowest values for phosphate, iron, nitrite, and ammonia values. This change may be a result of the IFF's fish and fertilizer feeding operations.

Table 1

Chemistry parameter on the sample site

Parameter	*ST 1*	*ST 2*	*ST 3*	*ST 4*
TDS	100	92	99	100
TSS	5	24	19	6
COD	3.9	26.1	15.8	19.8
BOD	0.7	4.8	3.1	2.8
DO	7.8	6.3	6.4	7.3
Phosphate	0.327	0.443	0.521	0.306
Iron	0.0557	0.0162	0.0162	0.0162
Nitrite	0.0153	0.0023	0.0013	0.0013
Nitrate	1.62	2.35	4.67	6.04
Ammonia	0.0003	0.0009	0.0004	0.0003
pH	7.5	7.7	7.3	7.4

ST1 – sample site 1; ST2 – sample site 2; ST3 – sample site 3; ST4 – sample site 4.

Figure 2 shows there is a difference in water quality based on OWQI and OIP. At ST 1, the water quality based on the OWQI (87.92) was found to be good, while based on the OIP (3.97) it is was qualified as slightly polluted. At ST2, the quality was found to be poor through the OWQI (67.87), while the OIP showed it is polluted (4.48). Another trend was, however, observed at ST3, with the water found to be very poor through both the OWQI (25.52) and the OIP (4.43). The ST4 has almost the same value (25.86) of OWQI as ST3 and the water was also reported to be polluted based on the OIP (4.12).

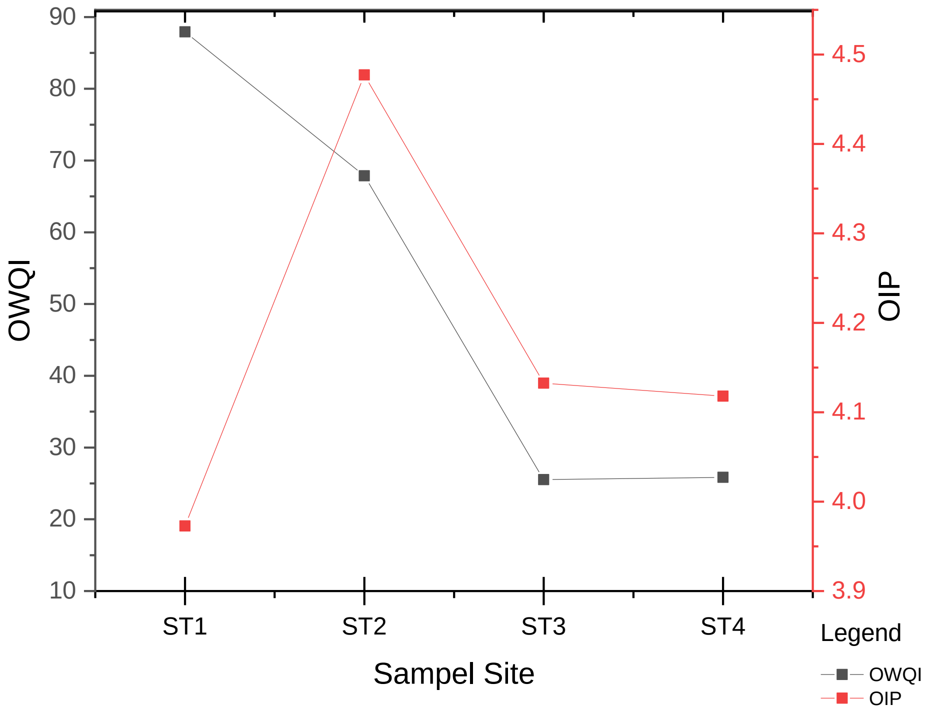

Figure 2. The water quality based on OWQI and OIP.

Phytoplankton index. There were identified 18 types of phytoplankton species at the sample sites, divided into three phyla which are Bacillariophyta, Cyanophyta and Chlorophyta. Cyanophyta has the highest number of individual phyla in the samples with the species observed to have included *Cymbella* sp., *Diatoma* sp., *Gomphonema* sp., *Gomphosphaeria* sp., *Gyrosigma* sp., *Hydrodictyon* sp., *Merismopedia* sp., *Microsytis* sp., *Sphaerocystis* sp., *Navicula* sp., *Nitzschia* sp., *Pediastrum* sp., *Phormidium* sp., *Pinnularia* sp., *Scenedesmus* sp., *Surirella* sp., *Synedra* sp. and *Ulothrix* sp. Moreover, ST2 had the highest number of individual phytoplankton species while ST1 had the least one, as indicated in Table 2.

Table 2

Individual species phytoplankton phyla taxonomic level on sample site

Phylum	*ST 1*	*ST 2*	*ST 3*	*ST 4*
Bacillariophyta	11	20	51	31
Cyanophyta	11	65	4	52
Chlorophyta	4	25	11	19
Total	26	110	66	102

ST1 – sample site 1; ST2 – sample site 2; ST3 – sample site 3; ST4 – sample site 4.

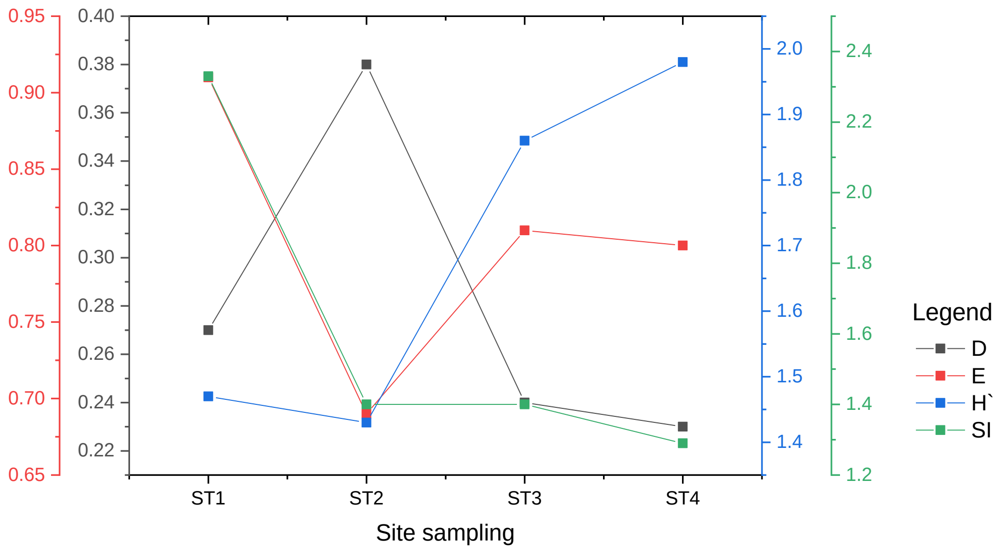

Figure 3. Water quality based on ecology index and SI.

Figure 3 shows a revamp in the D, E, H` and SI indexes' ecological values with the second sampling site recorded to have the highest D value while no significant difference was observed between the other sampling sites. Meanwhile, the most significant H`value was found in the output sampling site. The highest E value was discovered in the input sampling site while there is no much difference in the other sites. Moreover, the SI value at the output sampling site was the highest and this means it is in the oligo-saprobic class or has a very slight pollution level (Dresscher & van der Mark 1976). The SI value in ST2 decreased and changed to become slightly polluted and this was also observed with ST3 and ST4.

Comparison of sample site. Table 3 illustrates the comparison using chemical parameters. There is a discrepancy between the calculated and observed p values because the calculated p-value is less than the observed p-value (0.05). This may be described as variations in the chemical parameters used to calculate OWQI and OIP values, resulting in discrepancies in the outcomes of water quality values calculated using OWQI and OIP values for each sample site. Chemical parameter value discrepancies between inputs and outputs caused by IFF activity are thought to influence the quality of existing water.

Table 3

Comparison between sample sites based on the chemical parameters

Parameter	*N*	*Median*	*Ave rank*	*Z*
Ammonia	4	0.00035	2.5	-3.27
Fe	4	0.0162	10.5	-1.96
BOD	4	2.95	20.5	-0.33
COD	4	17.8	34	1.88
DO	4	6.85	30.6	1.33
Phosphate	4	0.385	14.5	-1.31
Nitrate	4	3.51	21.8	-0.12
Nitrite	4	0.0018	6.5	-2.61
pH	4	7.45	32.4	1.61
TDS	4	99.5	42.5	3.27
TSS	4	12.5	31.8	1.51
Overall	44		22.5	
H = 40.00 DF = 10 P = 0.000				
H = 40.02 DF = 10 P = 0.000 (adjusted for ties)				

H - Kruskal-Wallis H test; DF - Degree of freedom; P - P value.

Discussion. This study found there was a change in the water quality evaluation based on OWQI and OIP values. OWQI value changes can be due to changes in the nitrate values in water, while changes in the OIP values occur due to changes in the DO values. This can be caused by the use of chemical fertilizers and fish feed. IFF needs organic fertilizer for optimal rice growth (Mahmudiyah & Soedradjad 2018).

It has been observed that based on D value there are no dominant species, the community is stable and the environmental conditions are optimal, the D value approaching 0 (Magurran 1988). The highest value of D is found in ST2, which is dominated by *Gomphosphaeria* sp. This may be because the IFF region is prepared to plant rice and the fish are still empty, creating a perfect environment for the growth of *Gomphosphaeria* sp. in watery regions (Dalu & Wasserman 2018). While no significant difference was observed among the sites (H' value in the range of 1 to 3), all the sample sites are moderately polluted (Magurran 1988). E value shows that each of them has a high level of uniformity (Magurran 1988). SI value decreased severely from S1 due to the emergence of ɑ-Mesosaprobik plankton in other site samples. This study found that there has been a change in water quality due to the IFF method, but the water quality class has not changed drastically.

Conclusions. There is a pressing need to enhance food production via technological advancements without jeopardizing the environment. IFFs, which are a mix of fish farms and rice fields, have the potential to improve the food supply. Additionally, combining agricultural and fish farming operations combines not only production, but also environmental effects. The tests performed in this research revealed a change in the class of water quality, as determined by the OWQI, OIP, and SI, as a result of pollutants in the integrated fish farm field's input region. This conclusion was drawn because there was no change in the D, H, or E indices between the sample sites, but there was a change in chemical parameters, indicating that there is a change in water quality between the sampling locations as a consequence of IFF. The area got somewhat more polluted as a consequence of the change in the SI value, but this IFF technique has a modest effect on the environment.

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Conflict of interest. The authors declare no conflict of interest.

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