Water Quality Index as a Simple Indicator for Sustainability Management of Rural Landscape in West Java, Indonesia

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***Abstract*- Research on water quality in rural landscapes in four watersheds was conducted in the dry season period. Twenty-four villages in the west part of Java Island, Indonesia, were selected as the study sites. Water samples from springs, ponds, paddy fields and rivers in each village were analyzed. The water quality index (WQI) results showed that the water samples were in "good" and "medium" level. This condition proofed that rural landscapes have the ability to absorb and clean the water pollution through the natural process. Further analysis shows the negative correlation between WQI and TIN (sum of NH_4-N, NO_3-N and NO_2-N), which indicated the deterioration in water quality due to the addictive effect of inorganic nitrogen compounds. Furthermore, the negative correlation between WQI and dissolved oxygen (DO) indicates the water quality is still in low level which complies with the standard. In conclusion, as a useful method for water quality classification, the WQI is effectively applicable for the assessment of water quality in the rural landscapes. In addition, the results were easy to understand for the non-scientific public and decision-makers. The WQI is suitable for the water quality assessments for monitoring pollution control strategies, particularly in developing countries with limited budgets.**

Keywords*- *Agricultural Land; Rural Landscapes; Watershed Management; Water Quality Index; West Java Watersheds

I. INTRODUCTION

Rural landscapes in Indonesia are good examples for sustainability development in many sectors. Since agricultural activity is predominant in rural landscapes, it becomes an excellent concern to study about the impact of agricultural to the quality of landscapes and its vicinity. The use of pesticide and fertilizer is relatively high in some rural landscapes. However, most of the rural communities which have local wisdom are conducting their agricultural activity in conservative and low-contaminant way. Those communities intended to develop healthy landscape through cultures and behaviours to cultivate the agricultural land for sustainable environment. The idea of healthy landscapes is always reminding by the elders of rural communities.

A healthy rural landscape has protected water quality conditions which have been managed by rural communities as local wisdom. The rural community's wisdoms often manage the landscape by protecting and conserving water resources area through religion or tradition approach. Those wisdoms are such as protecting forest area, use soil-conserved plant, conserve water resources, utilize homestead plot and low-residual daily activity. However, those activities were usually inexplicitly known by those communities. Therefore, it is necessary to figure out the water quality condition related to sustainability of rural landscapes.

Traditional approaches to evaluate and monitor water quality are usually based on the comparison of the parameters values with the local normative [1]. Although developing formulas for calculating water quality are important to monitor the landscape quality, those provided formulas often give difficulty to imply and realize by local communities. A simple and easy method should be introduced and utilized among stakeholders at local level, such as the water quality index (WQI).

The water quality index (WQI) has been recommended as simple method to overcome many limitations found for the global water quality measurement as mentioned earlier. In addition, it has been used for public and decision makers to receive water quality information shortly and accurately [2]. The WQI is a mathematical formula which is calculated from the transformation of various kind of water characterizations data into water quality levels [3]. The WQI also permits to assess the changing of water quality and to identify water dynamics. It generally consists of sub-index scores assigned to each parameter by comparing the measurement with a variable-specific rating curve, mean value weighted, and combined into the proposed index. The WQI is widely used by many scientists around the world. It has been mentioned that WQI formula has been modified over 55 difference type of use [4]. The use of WQI could be of particular interest for developing countries, because they provide cost-effective water quality assessment as well as the possibility of evaluating trends [2].

The WQI value is simple and easily to be understand for local people and decision makers. The WQI has been applied for predicting the surface water condition in many countries, including Argentina [2], Mexico [5], Malaysia [6], Chile [7], India [8, 9], Nepal [10], Spain [3], Brazil [11], Iraq [12], Turkey [13], and China [1].

In this study, the WQI was applied to evaluate the four locations of water utilization, namely spring, pond, paddy field and river. The scores calculated were used for showing the water quality condition in rural landscapes of Indonesia. Furthermore, it is to show the impact of agricultural activities and rural communities behavior on overall water quality along the upstream to the downstream of watershed areas. Moreover, the river standards for pollution control and water quality management can also be prescribed in terms of the WQI [14].

The aims of this research are to evaluate the water quality in rural landscape and to figure out the watershed management along the water streams. The water quality in rural landscapes is hypothesized have a good level as the impact of a local wisdom in terms of agricultural utilization and community's behavior.

II. MATERIALS AND METHODS

A. Description of Study Area and Sampling Design

The study areas were located within four watersheds in West Java region, Indonesia, namely Ciliwung (CL) and Cisadane (CS) watersheds in the northern areas (NAs) and Cimandiri (CM) and Cibuni (CB) watersheds in the southern areas (SAs). These watersheds illustrate the condition of West Java region based on their orientation in the north and south of the island (Fig. 1). The total area, perimeter, main river length, climate condition and orientation of each watershed are shown in Fig. 2 and Table I. The delineation process was carried out using standard methods developed in watershed analysis [15-19]. Those watersheds were delineated in terms of ecological boundary, not accordingly to administrative boundaries. Therefore one watershed consists of more than two districts as shown in Table I. The main river lengths were the distance from the highest location to the lowest part following the main river corridor.

TABLE I GENERAL CONDITION OF FOUR WATERSHEDS

Watershed Name (Abbreviation)	Administrative Location (District)	Total Area (ha)	Perimeter (km)	Main River Length (km)	Climate Condition*
Cisadane (CS)	Bogor, Tangerang, Depok	153,485.47	273.50	112.7	A and B
Ciliwung (CL)	Bogor, Jakarta, Depok	89,036.33	221.84	82.9	A and B
Cimandiri (CM)	Sukabumi, Cianjur	196,947.51	207.05	55.8	B
Cibuni (CB)	Sukabumi, Cianjur, Bandung	147,052.32	232.02	34.3	B

*Climate classifications are based on Schmidt and Ferguson [20]

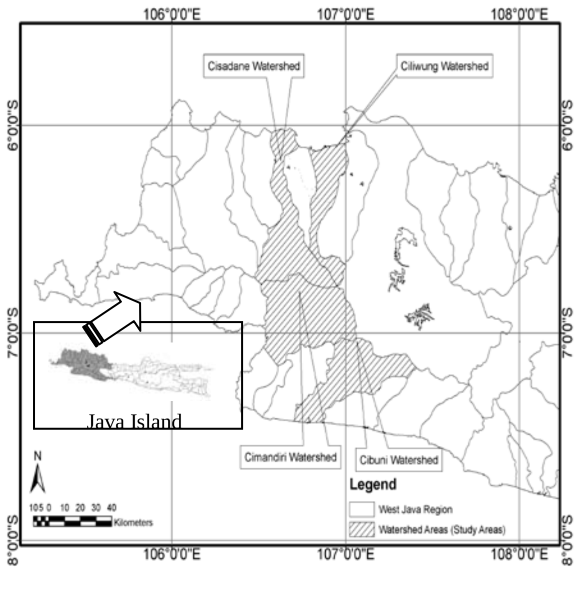

Fig. 1 The study areas of four watersheds, which two of them are located in the northern areas (NAs), i.e. Cisadane (CS) and Ciliwung (CL) watersheds, and other two are located in the southern areas (SAs), i.e. Cimandiri (CM) and Cibuni (CB) watersheds

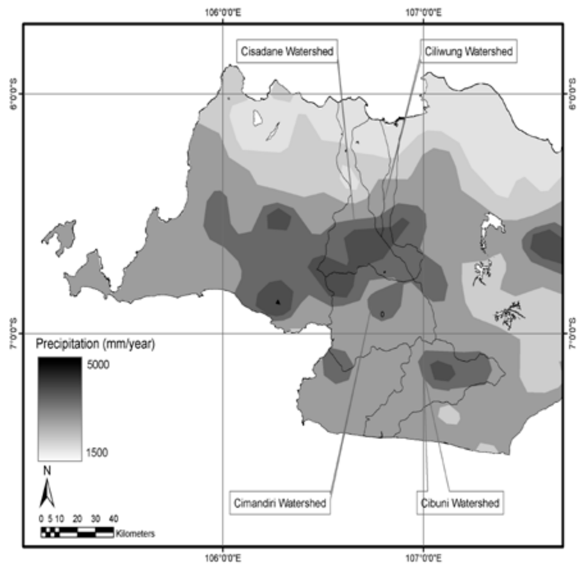

Fig. 2 The annual precipitation condition in study areas shows that the NAs climate conditions are more humid than the SAs

The climate conditions were determined by Schmidt & Ferguson's classification. The NAs have A and B classifications, while the SAs have B type (Fig. 2). The A classification means very wet region, tropical rain forest, and has more than ten wet months (monthly precipitation > 100 mm) per year. The B classification means a wet region, tropical rain forest, has eight to nine wet months per year. In general, the NAs were more humid than the SAs.

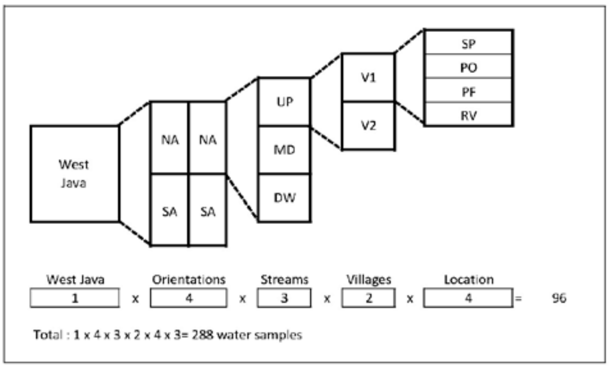

Fig. 3 Sampling procedure for determine number of water samples

In total, 96 samples of water samples have been measured with triplicate method. The procedure is as follows: 1) selected four watersheds (two in the southern areas (SA) and two in the northern areas (NA)), 2) selected three streams in each watershed (upstream (UP), middlestream (MD), and downstream (DW), 3) two villages were selected in each stream (V1 and V2), and finally 4) in each village, four locations were measured, i.e. spring (SP), pond (PO), paddy field (PF) and river (RV)

The sampling design was decided based on region, orientation, streams, villages and water sample locations. There is one region namely West Java region, and two orientation, i.e. southern areas (SAs) and northern areas (NAs). Those orientations were compared to evaluate the difference. Three streams namely upstream, middlestream and downstream were considered, which were located inside two villages. In each village, three water samples were examined from four water locations, i.e. spring, pond, paddy field and river (Fig. 3).

B. *Water Quality Index Parameters*

Eleven parameters were selected based on the previous experiences in other watershed [21]. Those parameters are dissolved oxygen (DO), chemical oxygen demand (COD), biological oxygen demand (BOD), nitrite (NO_2), nitrate (NO_3), ammonium (NH_4), phosphate (PO_4), alkalinity, pH, total *Escherichia coli* and total Coliform. All these parameters were measured in triplicate samples, and the results were shown as averages.

The WQI in this research was calculated on the basis of the former WQI formula proposed by Rodriguez de Bascaroan [2] as follows:

$$WQI = k\frac{\sum_{i=1}^{n} C_i P_i}{\sum_{i=1}^{n} P_i} \quad (1)$$

where k is a subjective constant with a maximum value of 1 for apparently good quality water and 0.25 for apparently highly polluted water, Ci is the normalized value of the parameters and Pi is the relative weight of each parameter in terms of its role for water in rural landscape communities. In this research, such as others studies written in the literatures that the constant k was not considered in order not to introduce a subjective evaluations [5, 22]. In addition, the 288 samples (96 locations with triplicate design) examined in the field were apparently in good quality appearance, therefore k can be omitted. The WQI value in the range of 0-25, 26-50, 51-70, 71-90, 91-100 represents the water quality level for very bad, bad, medium, good and excellent, respectively.

The weight (Pi) and normalization factors (Ci) of the parameters were adopted from ten literatures [1-3, 8-11, 13, 23, 24] and listed in Table II. The parameters used by those literatures are different from each other. The number of used and total parameters compare to the literatures is also shown in Table II.

The Pi value has been assigned ranging from 1 to 4 depending on the collective expert opinions taken from ten different previous studies. The mean values for each parameter along with the literature used are shown in Table II. In addition, a relative weight value of 4 was considered as the most significant (e.g. dissolved oxygen) and 1 as the least significant (e.g. phosphate from various literatures). This method also has been used by Alobaidy et al [12] by using ten parameters at Dokan Lake in Iraq. The mean values in Table II then were used for WQI formula in Table III. Pearson's correlation analyses for physical, chemical and biology parameters of water samples were calculated by using PASW 18 software.

III. RESULTS AND DISCUSSION

A. *General Results of Water Quality Index (WQI)*

Table IV shows the result of Pearson's correlation analysis among eleven parameters. Eleven parameters are correlated each other ($p \leq 0.01$ and $p \leq 0.05$), except between alkalinity and phosphate. Those parameters show positive correlations between others parameters except alkalinity. It is suggested that those eleven parameters are representative enough for WQI calculation.

The DO, COD, BOD, nitrite, nitrate, ammonia and phosphate have positive significant correlation ($p \leq 0.01$) for each other. Those correlations indicated the contamination of insoluble inorganic matters and the biotransformation of nitrogen among inorganic compounds. It is also suggesting that organic matter contamination often occurred with nitrogen loading in the water resources, particularly in rural landscapes area which are predominantly by agricultural land. The increasing nutrients in the surface water are correlated to eutrophication, which occurred in the ecosystem as corresponded to the addition of artificial or natural substances through fertilizers or sewage to an aquatic system.

TABLE II ASSIGNED WEIGHT VALUES ADOPTED FROM SOME LITERATURES

Parameters	Unit	Literature										Mean Value
		[1]	*[2]*	*[3]*	*[8]*	*[9]*	*[10]*	*[11]*	*[13]*	*[23]*	*[24]*	
DO	mg/l	4	4	4	4	4	4	4	4	4	4	4.0
COD	mg/l	3	3	3	-	3	3	3	3	-	-	3.0
BOD	mg/l	-	3	3	3	4	3	3	3	2	3	3.0
NO2	mg/l	2	2	2	-	-	2	2	2	-	-	2.0
NO3	mg/l	2	2	2	-	-	2	2	2	3	-	2.1
NH4	mg/l	3	3	3	-	3	3	3	3	-	-	3.0
PO4	mg/l	-	1	1	-	1	1	1	1	2	-	1.1
Alkalinity	mg/l	-	-	-	1	3	-	-	-	-	1	1.7
pH	no unit	1	1	1	4	4	1	1	1	1	4	1.9
Escherichia coli*	MPN/100ml	-	-	-	-	3	-	-	-	-	-	3.0
Total Coliform*	MPN/100ml	-	3	-	4	-	-	3	-	4	4	3.6
Number of Selected Parameter		6	8	8	5	8	8	9	8	6	5	
Total Parameters in the literature		7	20	11	9	15	17	26	17	12	9	

*Bacteria expressed as MPN/100ml (most probable number per 100 ml)

TABLE III RELATIVE WEIGHT (PI) AND NORMALIZED VALUES (CI) OF WATER QUALITY VARIABLES

Parameters	Pi	Normalization Factor (Ci)										
		100	*90*	*80*	*70*	*60*	*50*	*40*	*30*	*20*	*10*	*0*
DO	4.0	>7.5	>7	>6.5	>6	>5	>4	>3.5	>3	>2	≥1	<1
COD	3.0	<5	<10	<20	<30	<40	<50	<60	<80	<100	≤150	>150
BOD	3.0	<0.5	<2	<3	<4	<5	<6	<8	<10	<12	≤15	>15
NO2-N	2.0	<0.005	<0.008	<0.01	<0.04	<0.075	<0.1	<0.15	<0.2	<0.25	≤0.5	>0.5
NO3-N	2.1	<0.5	<2	<4	<6	<8	<10	<15	<20	<40	≤70	>70
NH4-N	3.0	<0.01	<0.05	0.1	<0.2	<0.3	<0.4	<0.5	<0.75	<1	≤1.25	>1.25
PO4	1.1	<0.025	<0.05	<0.1	<0.2	<0.3	<0.5	<0.75	<1	<1.5	≤2	>2
Alkalinity	1.7	<20	<40	<60	<80	<100	<120	<140	<160	<180	≤200	>200
pH	1.9	7	6.9-7.5	6.7-7.8	6.5-8.3	6.2-8.7	5.8-9.0	5.5-9.5	5.0-10.0	4.5-10.5	4.0-11.5	<4.0;>11.5
E. coli	3.0	<50	<500	<1000	<2000	<3000	<4000	<5000	<7000	<10000	≤14000	>14000
Fecal Coliform	3.6	<50	<500	<1000	<2000	<3000	<4000	<5000	<7000	<10000	≤14000	>14000

*All values are in mg/l, except for pH (no unit) and bacteria (MPN/100ml)

TABLE IV PEARSON'S CORRELATION COEFFICIENT AMONG WATER QUALITY PARAMETERS

	WQI	DO	COD	BOD	NO_2	NO_3	NH_4	PO_4	Alkalinity	pH	E. coli	Coliform
WQI	1	-.778**	-.794**	-.773**	-.788**	-.845**	-.868**	-.877**	.235*	-.416**	-.863**	-.861**
DO		1	.988**	.950**	.943**	.925**	.926**	.799**	-.321**	.430**	.911**	.910**
COD			1	.977**	.955**	.923**	.932**	.818**	-.298**	.400**	.912**	.911**
BOD				1	.927**	.882**	.890**	.796**	-.281**	.378**	.864**	.862**
NO_2-N					1	.939**	.940**	.828**	-.207*	.365**	.939**	.938**
NO_3-N						1	.966**	.819**	-.266**	.471**	.979**	.979**
NH_4-N							1	.841**	-.246*	.428**	.963**	.963**
PO_4								1	-.167	.258*	.849**	.846**
Alkalinity									1	-.628**	-.205*	-.204*
pH										1	.377**	.376**
E. coli											1	1.000**
Coliform												1

**. Correlation is significant at the 0.01 level (2-tailed)
*. Correlation is significant at the 0.05 level (2-tailed)

The eutrophication process can be human-caused or natural. Untreated sewage effluent and agricultural run-off carrying fertilizers are examples of human-caused for eutrophication. However, it also can be naturally in situations where nutrients accumulate or where they flow into systems on an ephemeral basis. Eutrophication generally promotes excessive plant growth and decay, and at the same time causes deterioration in water quality. Thus, give further results in the increasing concentration of organic matter and eventually deteriorates the water quality [25].

Descriptive statistic for examined eleven parameters is shown in Tables V and VI. It shows the minimum, maximum and the standard deviation from each parameter. In order to describe the situation on water quality in rural landscapes, some results from the determination of water quality parameters are discussed shortly below.

TABLE V DESCRIPTIVE STATISTIC FOR ALL PARAMETERS AS WATER CHARACTERISTIC OVER ALL

Parameters	Min.	Max.	Mean	Standard Deviation
DO	0.87	9.60	3.88	2.01
COD	2.87	29.14	11.44	5.96
BOD	0.13	6.71	2.28	1.66
NO_2-N	0.000	0.617	0.138	0.158
NO_3-N	0.010	4.670	1.446	1.358
NH_4-N	0.000	2.080	0.577	0.542
PO_4	0.010	4.683	1.438	1.262
Alkalinity	91.70	223.00	138.04	29.71
pH	6.95	8.41	7.68	0.42
E. coli	6.00	244.00	74.58	62.72
Coliform	6.00	260.00	79.51	66.96

*All values are in mg/l, except for pH (pH unit) and bacteria (MPN/100ml)

The values of DO, COD and BOD have never reached the critical value in all water resources, indicating good water quality condition. The observed average for DO is 3.88 mg/l complies with WHO standards and it is also considered good sufficient for human consumption and almost aquatic ecosystem. Unpolluted waters are likely to have BOD value < 3 mg/l, the maximum BOD found is 2.28 mg/l. It is indicated the biological activities in the water system are still in good conditions.

Nitrate was the most abundant from of nitrogen compounds (1.446 mg/l), while nitrite found in a small amount (0.138 mg/l). Ammonia was varied depend on the location, from nil up to 2.080 mg/l with average 0.577 mg/l. The possible sources of nitrogen in water sample locations are mainly from atmosphere, surface runoff, sewage discharge, agricultural fertilizer and organic waste. The correlation between WQI and all nitrogen compounds show a significant negative relationship ($p < 0.01$).

Phosphate concentration reached the range 0.010 - 4.683 mg/l, indicated high accumulation overflow polluted from agricultural fertilizer. In addition, sources of phosphate are also including human and animal wastes (i.e. sewage) and soil erosion.

The average for observed value of alkalinity is 138.04 mg/l, which was slightly higher than the permissible level recommended by WHO. It indicated the important value to determine the water quality rural condition. However, the positive correlation between WQI is only belonging to alkalinity ($p \leq 0.05$).

The results of pH varied from 6.95 to 8.41, indicating that water samples are almost neutral to sub-alkaline in nature [12]. The pH is an important factor that determines the suitability of water resources for various kinds of purposes [26]. The value also complies with the known values of some aquatic ecosystems.

The observed value of bacteria *Escherichia coli* and total coliform were very low, (<300 MPN/100ml), indicated the human and biological activity slightly undisturbed the water quality. The possibility of low contamination from bacteria is predicted because some households are using high phosphate contents material such as detergent and liquid bleach.

TABLE VI WATER PARAMETERS CHARACTERISTIC IN FOUR WATERSHEDS

Parameters	Watershed Name							
	CS				***CL***			
	Min.	***Max.***	***Mean***	***Std***	***Min.***	***Max.***	***Mean***	***Std***
DO	0.93	7.67	3.46	1.83	0.97	9.60	4.28	2.41
COD	3.50	20.30	10.14	4.90	3.07	29.14	12.47	7.22
BOD	0.17	4.15	1.83	1.28	0.33	6.27	2.47	1.81
NO_2-N	0.000	0.400	0.115	0.124	0.000	0.617	0.186	0.208
NO_3-N	0.013	4.327	1.563	1.493	0.013	4.670	1.637	1.543
NH_4-N	0.000	1.860	0.643	0.600	0.000	2.080	0.646	0.596
PO_4	0.017	3.057	1.138	0.976	0.017	4.683	1.720	1.521
Alkalinity	95.00	215.33	142.83	33.64	91.70	174.00	126.74	20.56
pH	6.95	8.41	7.77	0.46	6.95	8.40	7.67	0.40
E. coli	9.00	198.00	81.63	66.01	6.00	244.00	85.54	80.03
Coliform	10.00	214.00	87.54	71.14	7.00	260.00	91.04	85.34

Parameters	Watershed Name							
	CM				***CB***			
	Min.	***Max.***	***Mean***	***Std***	***Min.***	***Max.***	***Mean***	***Std***
DO	0.87	7.80	3.82	1.82	1.03	8.57	3.97	1.97
COD	2.87	23.05	11.53	5.76	3.93	25.29	11.63	5.90
BOD	0.23	5.88	2.37	1.62	0.13	6.71	2.46	1.88
NO_2-N	0.000	0.463	0.131	0.151	0.000	0.423	0.121	0.135
NO_3-N	0.010	3.867	1.348	1.286	0.013	3.633	1.235	1.118
NH_4-N	0.000	1.753	0.520	0.511	0.000	1.357	0.500	0.467
PO_4	0.010	3.540	1.377	1.224	0.010	3.293	1.517	1.276
Alkalinity	96.00	223.00	152.27	33.50	94.70	185.30	130.31	23.20
pH	6.98	8.20	7.64	0.42	7.02	8.33	7.63	0.41
E. coli	8.00	170.00	68.21	53.75	6.00	150.00	62.96	47.30
Coliform	8.00	179.00	72.58	57.09	6.00	158.00	66.87	49.95

*All values are in mg/l, except for pH (pH unit) and bacteria (MPN/100ml).

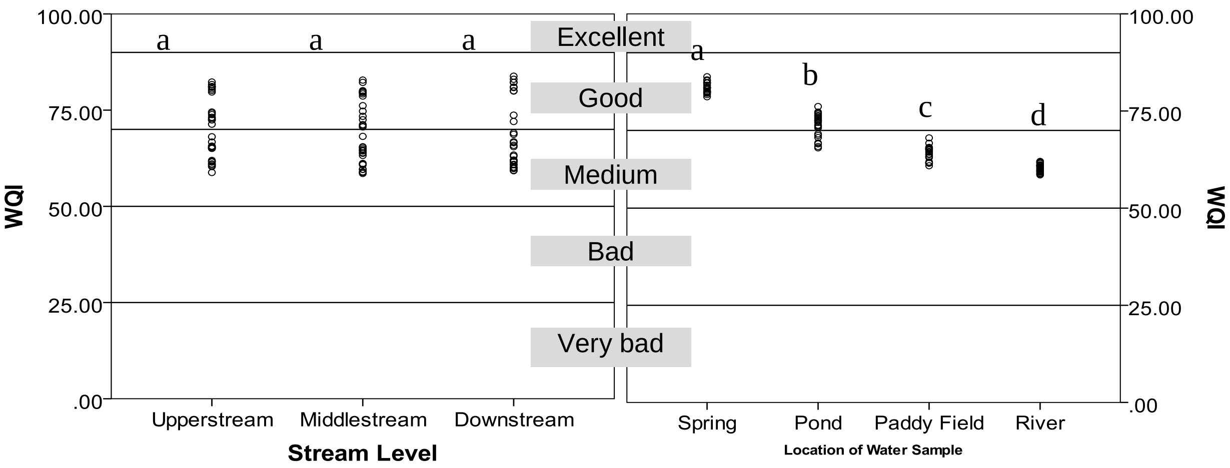

Fig. 4 Classification of WQI at level of streams and water sample locations. All WQI values are at good-medium level. The different letter show the mean difference is significant at the 0.05 level

The WQI has negative correlation to all parameters, except alkalinity, which indicated the possibility of organic pollution effect in rural landscapes was very low. It shows that the behaviour of organisms inside the ecosystems is in balance conditions. All WQI values have fallen under “Good” and “Medium” water quality (Fig. 4).

B. The WQI by Streams

There is a tendency that the WQI was decreasing from upstream to downstream (Fig. 5). However, the contaminations in the upstream, particularly at paddy field, were occurred as the impact of pesticide and fertilizer utilization. Nevertheless, the WQI were still in “good” to “medium” level, which means the level of contamination is in allowed concentration. In some places, ground and surface water have shown the need for monitoring of pesticide contamination in surface and groundwater [27]. However, the high level of nitrogen concentration can be come from human activities [28] or households domestic sewage [29]. In addition, the high concentration of some nutrients in water can be also impacted by livestock. Under base flow conditions, in-stream and/or riparian processes played a significant role in controlling general chemical nutrient, particularly in the upstream which were impacted by livestock [30].

The decreasing water quality is believed as the impact of some disturbances that have been caused by rapid changes in land use and land cover, deforestation, the application of monoculture farming systems in commercial agriculture, urbanization, industrialization, and other types of infrastructure development [31]. However, since rural landscapes among 24 selected villages are low-rate of changing in land uses and low-rate of deforestation, it made the WQI value still in permitted level.

Although the downstream of CS and CL watersheds is populated and urbanized, the rural landscapes were in properly managed situation. The influence of industrialization is also low-impact because it centralized at close to urban area. The selected villages are located remote from populated and facilitated urbanize area, which makes the WQI value still in permissible level.

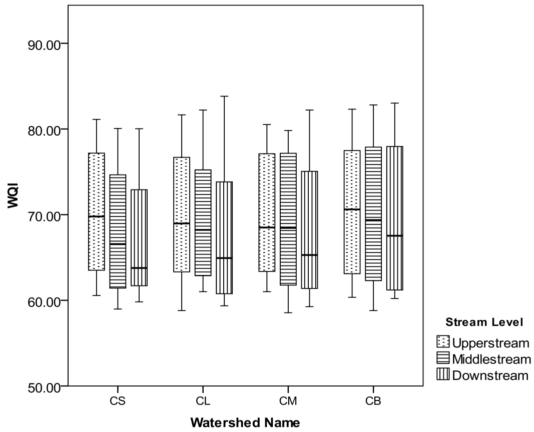

Fig. 5 The comparison of WQI value among stream level at all watersheds

C. The WQI by Sample Locations

Among four locations, the highest to the lowest WQI values are springs, ponds, paddy fields and rivers, respectively (Fig. 6). Springs burst out from underground water which have low contaminant because they were filtered naturally by ground or soil layers. However, rural settlements are most likely to be developed close to springs, therefore some contaminations are found but in the low level.

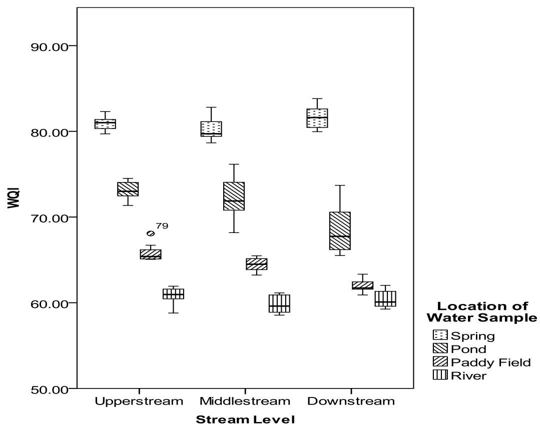

Fig. 6 The comparison of WQI value among water sample location at stream level

The WQI values at ponds highly varied from 65.51 to 76.16. It is because the utilizations of ponds are differed. Some ponds are being used as fish ponds, some are being used for household daily activity and some are both. The behavior of rural communities to use ponds for supporting daily activities is impacting to the level of nitrogen concentration [28]. The fishpond management, such as feeding, harvesting and cleaning, made the inorganic nitrogen increase.

A few vary WQI value at paddy fields (60.91 to 68.08) indicates that the utilization of fertilizer and chemical pesticide among all stream level are equal. It is because people tend to increase the production by using intensification technique. However, not all paddy fields were cultivated in highly intensive way, because rural community's local wisdom teaches the plant rotation method between rice and crops. In addition, for the agricultural areas, riparian corridors are vital for protecting biodiversity and water quality [32]. In general, the paddy fields are located predominantly outside settlement area, which surrounded by agroforestry system, such as mixed garden and bamboo garden (talon).

D. *Further Analysis of WQI Values*

Further analysis shows the correlation between WQI and TIN (sum of NH_4-N, NO_3-N and NO_2-N concentration in mg/l) (Fig. 7). It indicated the deterioration in water quality due to the addictive effect of inorganic nitrogen compounds. Such deterioration, also occurred in the most populated area and after urban areas, as the development in rural landscapes is majority close to the facilitated area [21]. Moreover, the correlation between WQI and DO is also shown in Fig. 8. The negative correlation indicates the DO values are still in low level which complies with the WQ standard.

E. *Sustainability of Rural Landscapes*

In rural landscapes, it is far simple to identify each patch of the agricultural system boundary. The mosaic of agriculture that uses water sustainability is relatively simple to understand. However, the concept of sustainability as a whole has been much harder to define [33]. Therefore, it can be concluded that the rural landscapes in each watersheds are more sustainable as a resource of purification and pollutant absorption area identified by WQI value.

Moreover, in contrast to agricultural commodities, environmental services in rural landscapes are often undersupplied by communities due to absent or weak pricing signals [34]. These services may involve biodiversity protection, water quality enhancement, microclimate improvement, maintenance of cultural heritage and the provision of recreational opportunities and landscape scenery [35]. Societal demand for these services is strong and growing. People are seeking more than just food production from rural landscapes [36].

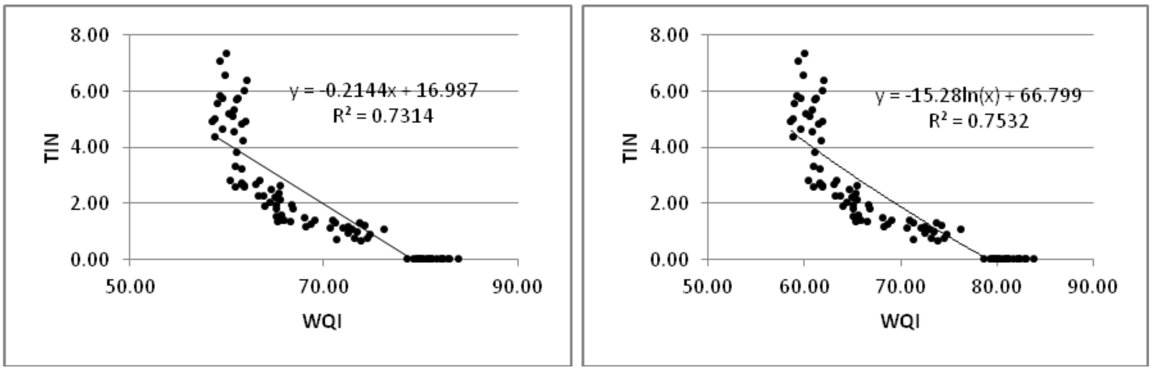

Fig. 7 Regression diagram between WQI and TIN in study areas is expressed by linier equation y = -0.2144x + 16.987 with R² = 0.7314 and/or exponential equation y = -15.28ln(x) + 66.799 with R² = 0.7532

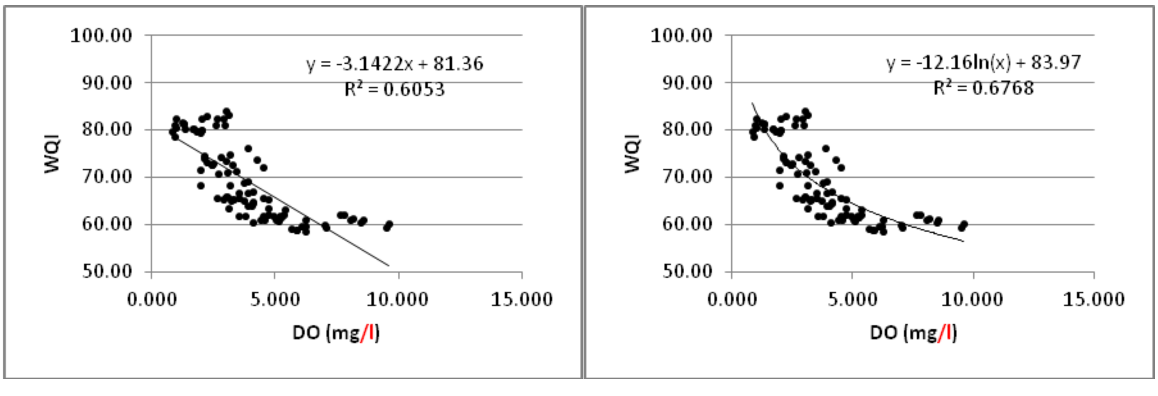

Fig. 8 Regression Diagram between WQI and DO is expressed by linier equation y = -3.1422x + 81.36 with R² = 0.6053or exponential equation y = -12.16ln(x) + 83.97 with R² = 0.6768

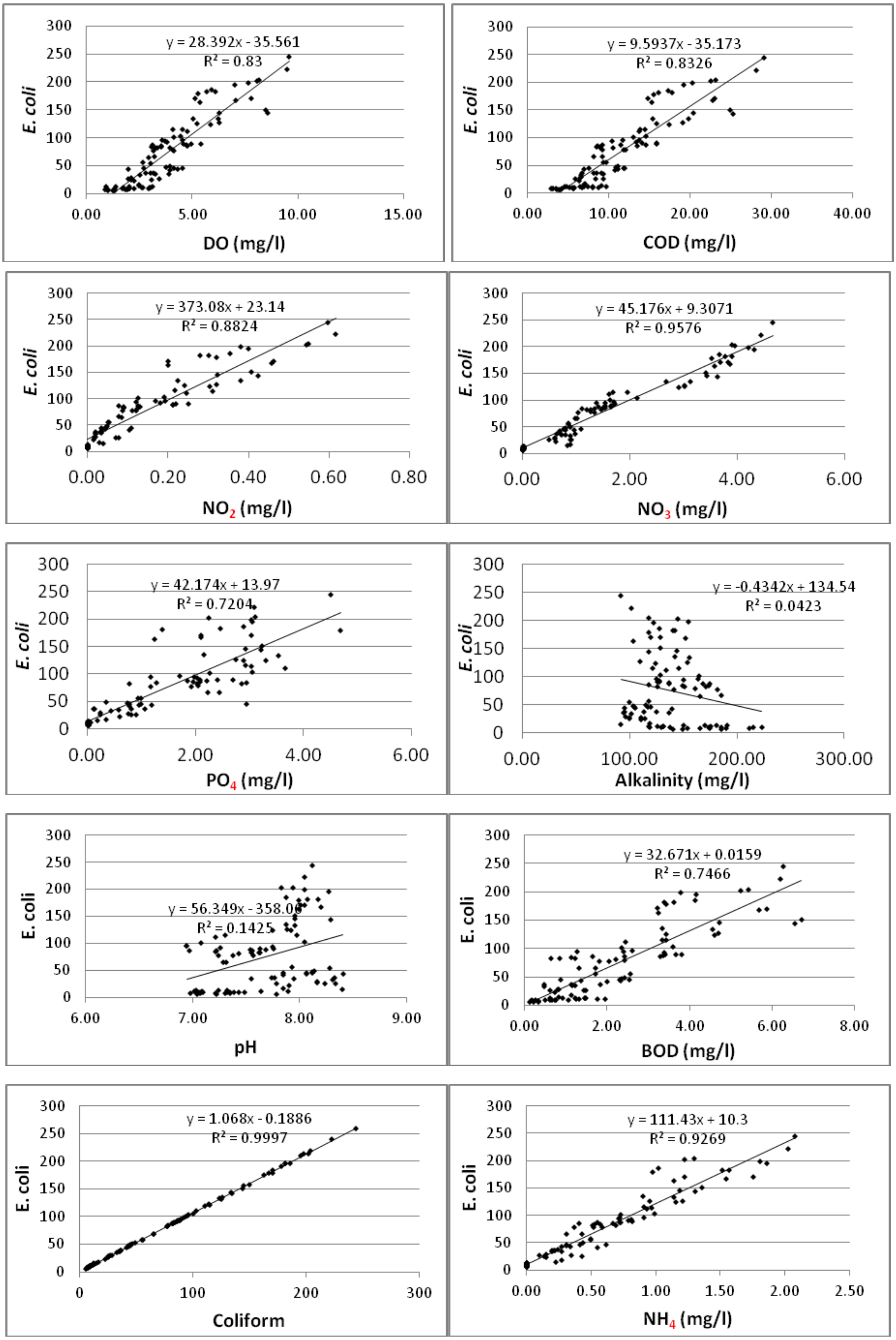

Fig. 9 Relationship between *Escherichia coli* and other 10 water quality parameters

All parameters show positive correlation to *Escherichia coli*, except alkalinity

Most significant contamination of water resource originates from domestic sewerage. Based on WQI value, it is important to set up a restoration system at the most suitable points of water stream with low cost and low energy input. Using charcoal and plants to remove those contamination has been suggested [37]. One of water improvement practices [38] is by using priority scenario that increases agroforestry system production and the sustainably of rural landscapes. Other research also found that abandoned paddy fields remaining in mixed urban/rural areas have significant potential to reduce both nitrogen and phosphorous loads [39].

The river as the last accumulation of water material from any resources plays both positive and negative role. As positive role, the river can clean the water pollution by absorbing the pollutant through plants, soil and sometimes animals. A research shows that the plant was found to significantly contribute to the self-cleaning capacity of the river [40].

One approach to achieve sustainable management of water resources is ecohydrology [41]. The degradation of freshwater ecosystems and those of water resources have to consider the disruption of water and nutrient cycles, because pollution in rural landscapes can be substantially eliminated by biotechnology. Rural landscape management dealing with the optimization of ecotone zones structure in whole watershed, and usually a lack of space for ecohydrological relevant structure, and a lack of funding, although ecotone and other structural biotic elements provide the basis for sustainable landscape management [42].

A study showed that rural communities are intrinsically motivated to practice conservation by such factors as their attachment to their land, rather than by motivations such as receiving economic compensation [32]. A landscape ecology discipline, as a study of relations on the earth's surface can tackle planning and management issues from numerous view points, each with its own focal points [36], particularly in rural landscapes. Some studies show that rural landscapes play a significant role through agroforestry landscape managements [43]. The abilities to maintain the local wisdom knowledge to maintain the environmental quality are more likely the best options for achieving sustainable management in rural landscapes.

The communities are also likely to engage in conservation practices that make the land appear well-managed. Moreover, those communities with strong intrinsic motivations were likely to adopt conservation practices that protect streams, such as maintaining a woody vegetative buffer or practicing no-till farming. This study shows that protecting water resources location in agricultural watersheds requires strategies for conservation that synergic together with rural communities to acknowledge their local wisdom.

IV. CONCLUSIONS

The water quality in rural landscapes, particularly in four watersheds, was evaluated by water quality index (WQI). All water samples are situated at "good" and "medium" level. Overall, rural landscapes water quality is still in permitted level. Those conditions proofed that rural landscapes had the ability to absorb and clean the water contamination through the natural process. However, the use of fertilizer and chemical pesticide should be monitored because some indicators of inorganic maters showed likely tendencies to polluted water. The rural communities and government have to maintain this situation by simultaneously aware of local wisdom advice from the elders.

In conclusion, as a useful method for the classification of water quality based on scientific criteria, the WQI is effectively applicable for the assessment of water quality in the rural landscapes. In addition, the results were easy to understand for the non-scientific public and decision-makers. Moreover, the evaluation of WQI is suitable for the water quality assessments for monitoring pollution control strategies, particularly in developing countries with limited budgets. Some strategies can be adopted such as using charcoal and bio-remediation plants [37], activated carbons prepared from H_3PO_4 [44], or from haydite and quartz sand [45], increasing agroforestry system [38], planning integrated vegetation design [46] and with huge effort by constructing a wetland [47].

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