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The Role of Riparian Vegetation in Secondary Irrigation Channels at Slamet Village, Tumpang District, Malang Regency to Improve Irrigation Water Quality

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Abstract Secondary irrigation channel in Slamet Village has four types; the irrigation channel of the riparian vegetation with two sides and trees, two sides riparian vegetation without trees, only one side riparian vegetation, and without riparian vegetation. This study aims to determine the riparian vegetation and water quality profile in four types of secondary irrigation channel at Slamet Village, and to figure out the interaction between riparian vegetation and water quality. Water quality that is measured includes temperature, pH, conductivity, turbidity, DO, and BOD. In addition, riparian vegetation community structure was also observed in each irrigation channel. Riparian vegetation was analyzed by determining the abundance and diversity index, while water quality was analyzed by using bar charts. The relationship between riparian vegetation and water quality was analyzed by employing cluster and biplot using the PAST 3.20 program. The results showed that there were differences regarding the diversity index values of riparian vegetation in each irrigation channel. Each irrigation channel has a diverse riparian vegetation community structure. Irrigation channels with two sides riparian vegetation and trees have better water quality than other types of the irrigation channels. This is indicated by the high value of taxa richness (42 herbs species), H' index (5.12), *evenness* (0.95), DO (5.49) and low of a dominance index (0.03). Irrigation channels without riparian vegetation have low diversity and DO index. However, based on Government Regulation of the Republic of Indonesia No.82 of 2001, the water quality of the four types of irrigation channels still meets the quality standards of class II. Therefore, it can be concluded that the profile of riparian vegetation indirectly correlates with water quality.

Keywords Riparian vegetation, Water quality, Secondary irrigation channels

1. Introduction

Malang Regency is one of the districts in East Java Province which has high potential in the agricultural sector. About 1.394.5 km^2 of 3.535 km^2 in total area of Malang Regency is used for agricultural land (East Java Provincial Statistics Agency, 2013). Conventional farming practices using chemical fertilizers are still widely applied by farmers in Malang Regency. The use of chemical fertilizers will have implications for pollution of water sources used as irrigation facilities. Pollution of irrigation water will trigger a decrease in water quality which has an impact on eutrophication and algal blooming (Retnaningdyah, C., Suharjono, A. Soegianto, B. Irawan, 2010).

On the other hand, the decline of irrigation water quality was also caused by changes in the design of irrigation channels and the degradation of riparian vegetation.

Degradation of riparian vegetation causes mechanical riparian functions, as a source of nutrition, and as phytoremediation decreases (Agustina, L., 2013). Based on the Agriculture Minister Decree No.2 of 2019 about Technical Guidelines for Irrigation Network Rehabilitation, regulation of irrigation channels are made from thin reinforced concrete walls made by hydraulic cement mortar. This is because this irrigation building has several advantage, such as increasing efficiency and reducing water loss due to leakage and seepage. In addition to avoiding blockages in the flow of irrigation water into rice fields. However, not all secondary irrigation channels in Slamet Village are made from stone walls. Secondary irrigation channel in Slamet Village has four types; the irrigation channel of the riparian vegetation with two sides and trees, two sides riparian vegetation without trees, only one side riparian vegetation, and without riparian vegetation. Riparian vegetation is known to play a role in maintaining and improving irrigation water quality by being able to reduce nitrate contamination in fertilizers (Oktaviani, R., & Yanuwiadi, B., 2016). Riparian vegetation has also been known to act as a phytoremediation agent for chemicals and contaminants in

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the aquatic environment. The ability of water purification by riparian is an important factor that determines the success of phytoremediation (Dhir, 2013).

Mukhtar's (2010) study concluded that planting various plants in the asteraceae family, such as *Helianthus annus* has the potential to reduce lead (Pb) and nickel (Ni) in polluted waters with an effectiveness until 85%. Other riparian vegetations such as *Sesbania grandiflora* have the ability to reduce KMnO4, TDS, orthophosphate and ammonium levels, *Cyperus rotundus* functions to phytoextraction mercury levels in contaminated soil, and accumulates Sn, Zn, As, Cu and Pb (Siahaan, 2014). Based on the above, the purpose of this study is to determine riparian vegetation and water quality profile in four types of secondary irrigation channels at Slamet Village, and determine interaction between riparian vegetation and water quality.

2. Materials and Methods

2.1. Description of the Study Area

Figure 1. Map of Slamet Village

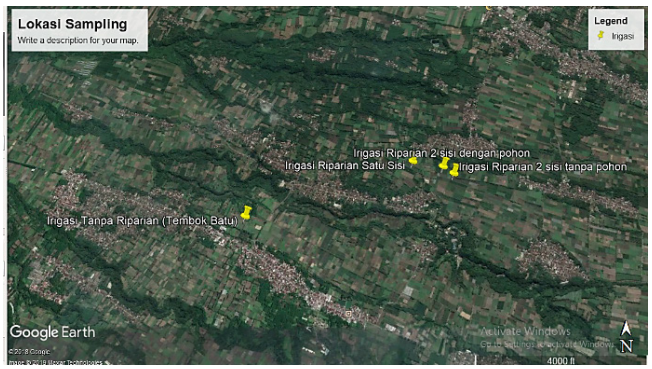

Figure 2. Sampling Locations of in Slamet Village

This study was conducted from February 2018-August 2018 in four types of secondary irrigation channels with different riparian conditions at Slamet Village, Tumpang District, Malang Regency. In each type of irrigation channel, 3 locations were chosen as replications. Identification of riparian vegetation was identified in the morning. While water samples and data analysis were identified and analyzed in the Laboratory of Ecology and Animal Diversity, Department of Biology, Faculty of Mathematics and Natural Sciences, University of Brawijaya Malang.

2.2. Sample Collection

Each type of riparian vegetation is calculated based on coverage, lushness and density. Riparian vegetation that found was recorded, observing the morphological character and status of species belonging to the exotic species or not. Observations of riparian vegetation are classified into two groups, i.e. herbs and shrubs with trees.

On the other hand, water quality is calculated based on several parameters, including the water temperature measured by a digital thermometer, turbidity with turbidity meters, conductivity with conductivity meters, pH with pH meters, DO and BOD measured by the titration method.

2.3. Data Analysis

The results riparian vegetation and water quality analysis were analyzed using Ms. Excel and the ANOVA test using SPSS v16.0 program, then followed by Tukey HSD (if the data variant is homogeneous) or by Brown-Forsythe test and then followed by Gamess-Howell (if the data variant is not homogeneous). Riparian vegetation is represented by determining the shannon-winner diversity index, evenness index, dominance index, and taxa richness. All data on riparian vegetation and water quality were analyzed by cluster and biplot using the PAST 3.20 program.

3. Result and Discussion

3.1. Riparian Vegetation Profile of Four Types Secondary Irrigation Channels at Slamet Village, Malang Regency

Riparian vegetation profile of four types of irrigation channels is described through the shanon-winner index (H'), *evenness* index (E), dominance index (C), and taxa richness (TR). The vegetation community structure that has been observed in all four locations shows various variations. In the four observation locations found 41 species of herbs and 15 species of shrubs and trees. The highest H' value of herbs in irrigation with two side riparian vegetation with trees combination (5,12) and the lowest H' value in the stone wall irrigation channel (2.73) (Table 1). According to Barbour et al., (1987) the value of the diversity index can range from 0-7, with criteria: 0-2 (low), 2-3 (moderate), and >3 (high). So, the results of diversity index analysis show that four locations still have high diversity. It because H' value for all locations is more than 3.

Eveness (E) index value ranges from 0.71 to 0.95, so it is classified as stable. More smaller the E value close to zero, the more uneven distribution of species and its dominated by certain types (Barbour et al., 1987). In other words, if the E value gets higher, the level of population uniformity will also be higher, where the number of individuals in each species can be said to be the same. Whereas, based on species richness, the highest value in the first location (42) and the lowest in fourth location (8). Taxa richness are refers to the number of species that found. When more species are found,

the level of richness taxa will be even higher, regardless of the amount of abundance in each species.

Table 1. Diversity and abundance index values in four types secondary irrigation channels

	Herbs				
Location	C	TR	H'	E	
Two Site Riparian Vegetated (Herbs, Scrubs, Trees)	0.03	42	5.12	0.95	
Two Site Riparian Vegetated (Herbs)	0.08	21	3.82	0.88	
One Site Riparian Vegetated	0.11	16	3.42	0.85	
No Riparian Vegetated	0.17	8	2.73	0.71	
	Shrubs & Trees				
Location	C	TR	H'	E	Abundance
Two Site Riparian Vegetated (Herbs, Scrubs, Trees)	0.34	15	2.21	0.57	1277
Two Site Riparian Vegetated (Herbs)	0.00	0.00	0.00	0.00	0.00
One Site Riparian Vegetated	0.00	0.00	0.00	0.00	0.00
No Riparian Vegetated	0.00	0.00	0.00	0.00	0.00

Then, based on the results of the dominance index (C) analysis, it showed that dominance value in herbs category ranges from 0.03 to 0.17. Thus, it can be explained that generally in locations with high riparian vegetation there is no dominance of riparian plants and dominance occurs in locations without riparian.

On the other hand, based on the results of each species is evenly distributed. Thus, the evenness and diversity index is also high. This result is in accordance with Soegianto (1994), that a community can be said to have high species diversity if the community is composed by many types with the same or almost the same abundance. Riparian vegetation in fourth location is dominance by *Chloris barbata*. *Chloris barbata* is a weed that is an invasive plant, its development is very fast and forms a tight community so that it can hinder the development of other plants (FAO, 2010). But this species is potential to be phytoremediator which is tolerant to mercury (Patra, 1994).

In first location there was codominance of several species such as *Syngonium podophyllum, Mikania cordata, and Imperata cyliandra, Alocasia odora, Brachiaria sp. Pteris vittata* and *Pteris beaurita* are members of the Pteridaceae family that have excellence of being a hyperaccumulator against Arsenic. This is according to Jose (2009) research, that *Pteris vittata* is an arsenic hyperaccumulator of more than 1000 mg of Arsenic per kg of dry shoot buds. Then, the results of Titi's (2005) study state that *Mikania cordata* is able to absorb lead (Pb) in land and waters contaminated with heavy metal waste in gold mines. Meanwhile, *Imperata cyliandra* has the ability to extract Zn from polluted soil (Ashraf, 2013) and absorb Pb from contaminated soil (Paz-Alberto, 2007). Even though, *Brachiaria sp.* is tolerant and adaptive in land that contaminated with crude oil (Suryati, 2016).

Riparian vegetation in shrubs and trees category was only found at first location, that is irrigation with two sides riparian vegetation and trees combination. The H' value is 2.12. The H' value is classified as moderate because it's between 2-3. Shrubs and trees were only found in first location because riparian vegetation in location 2, 3 and 4 irrigation channels was degraded and natural irrigation channels were converted into stone walls. *Eveness* index value at first location is 0.57. Taxa richness has 15 riparian species (Table 1). The dominance index (C) in this location is 0.34.

Species that dominate at first location in shrubs and trees category is *Musa paradisiaca. Musa paradisiaca* is used by farmers to take their leaves, flowers and fruit to increase economic value. But on the other hand *Musa paradisiaca* can acts as an accumulator of Cu ions (Kok, 2014). In addition, the second species which also has a high number that found is *Pennisetum purpureum. P. Purpureum* is a plant that has high competitive power, which is able to utilize natural resources (which are limited), and has high adaptation and tolerance to various environmental factors (Sanderson, 2009). This species plays a role in improving soil conditions damaged by erosion and acts as a phytoremediator. Another species found with the third largest amount is *Centrosoma pubescens*. According to Syarif (2007) research, *Centrosoma pubescens* is able to absorb large cyanide in the canopy and absorb the largest mercury in its roots. Trees species found include *Cocos nucifera, Bambusa sp., Hibiscus tiliaceus, Ficus septica, and Ceiba pentandra. Cocos nucifera* is used by farmers to increase economic value because its use of stems, leaves and fruit.

3.2. Water Quality Profile of Four Types Secondary Irrigation Channels at Slamet Village, Malang Regency Based on Physical-Chemical Parameters

Physical and Chemical parameters can be used as the indicators of water quality. The result of water monitoring indicates that the water temperature shows a considerable variation in the range of 22.11-28.26°C (Figure 3). The highest water temperature value is in the irrigation channel without riparian vegetation, and the lowest one is in the irrigation with two sides of riparian vegetation and trees combination. The water temperature is suitable for plants growing in the range of 20-30°C. Water temperatures which contain more than 30°C can cause damage and decay the plants. A high value of water temperature in the locations without riparian vegetation is strongly influenced by the lack of riparian vegetation covering at the edge channels. Finally, this causes irrigation channels to be exposed to the direct sunlight. Water temperature also plays an indirect role in river animals through DO arrangements. The Increased temperature will reduce pH and DO (Lee, 2004). Based on the results of the ANOVA test and Tukey-HSD test, water

temperature shows significant differences with the increase in water temperature in each location.

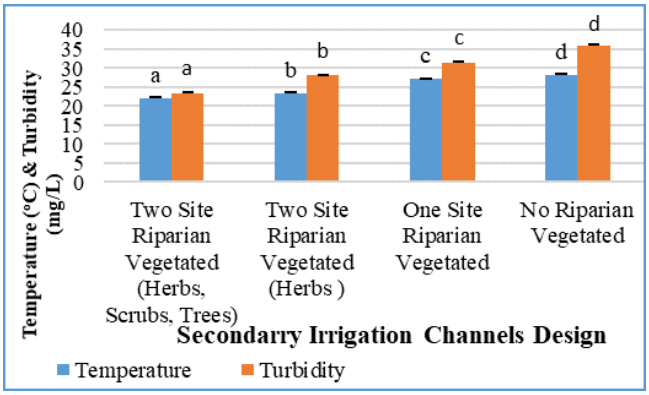

Figure 3. Average of temperature and turbidity values in four secondary irrigation channels design

Based on the Figure 3, the turbidity value in the four locations ranges from 23.27 to 36.10 with the optimum value ranging around 5-30 NTU. The highest value is in irrigation without riparian vegetation, and the lowest one is in irrigation with two sides riparian vegetation and trees combination. The high value of turbidity at irrigation without riparian vegetation is due to the low oxygen levels. Then, this causes the inability of plants and phytoplankton to photosynthesize for produce oxygen (CAWST, 2009).

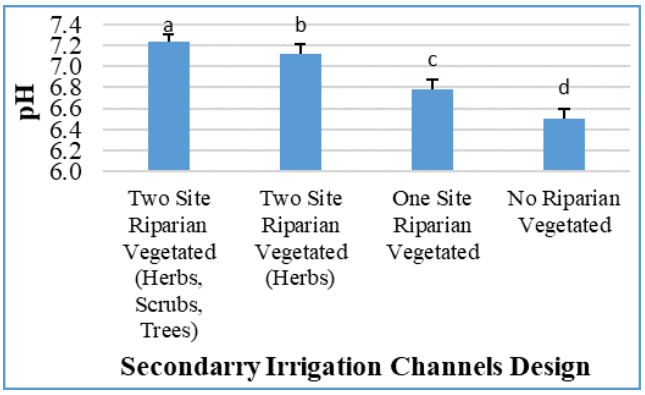

Figure 4. pH values in four secondary irrigation channels design

The pH value in the four irrigation channels design ranges from 6.5 to 7.23 (see Figure 4). The lowest pH value is found in the fourth location without riparian vegetation (6.5), and the highest one is in the first location (7.23). The pH value in all irrigation channels is categorized into normal classes with second and third grades which ranging from 6 to 9 in accordance with Government Regulation of the Republic of Indonesia No.82 of 2001 about Water Quality Management and Water Pollution Control. The high pH value at the first location is caused by natural irrigation channel condition with a very high cover of riparian vegetation. The presence of riparian vegetation can be used as a phytoremediator, that causes the process of organic acid mineralization in wastes to be absorbed by plant roots (Tanaka, 2016). Based on the ANOVA test results and Tukey-HSD test, the pH values are significantly different in each location.

The Conductivity value in four locations describes in Figure 5. The lowest conductivity value is in irrigation with two sides riparian vegetation and trees combination (134 µS/cm) and the highest one is in a location without riparian vegetation (182.13 µS/cm). Conductivity values of the four research locations are considered normal. According to FAO, the conductivity value is suitable for irrigation channels with a range of 0-3dS.m-1 (Ayers, 1994), and based on the results of the ANOVA test and Tukey-HSD, the results show that there are significant differences in the first and fourth location.

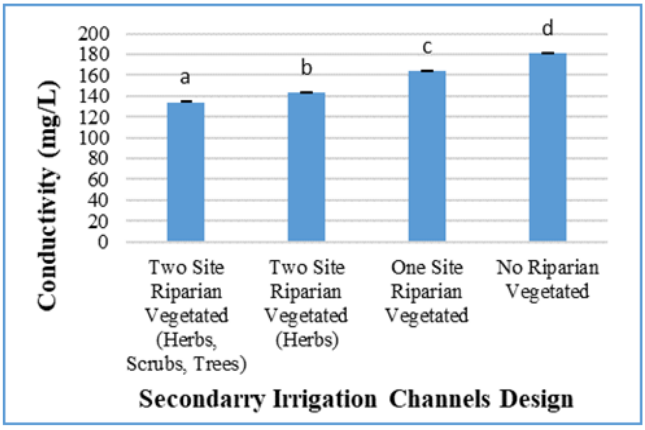

Figure 5. Conductivity values in four secondary irrigation channels design

The results of dissolved oxygen (DO) measurement in the fourth locations show good conditions because the results are in accordance with the class II quality standards (more than 4mg/L value). The highest DO values are in the first location with 5.49 mg/L and the lowest one is in the fourth location with 4.12 mg/L (Figure 6). A high DO levels at irrigation with two sides riparian vegetation and trees combination indicates that the condition of the water is still pure, and consisting of high oxygen levels. DO can be derived from the photosynthesis of riparian vegetation around irrigation channels. Thus, the higher number of riparian vegetation will positively be correlated with DO levels. DO concentrations are influenced by temperature, riparian vegetation, and salinity (Lee, 2004). Dissolved oxygen (DO) can be used as an indicator of water chemical quality, and this will affect the carnivorous fish group presence that integrated into the food chain cycle at the aquatic ecosystem (Seminu, 2013).

BOD is one indicator of organic pollutants in irrigation water. According to Mason (1994), Biochemical Oxygen Demand (BOD) is a characteristic that shows the amount of dissolved oxygen needed by microorganisms to decompose organic matter in aerobic conditions. The BOD value at the four study locations is between 3.96-5.66mg/L. The highest BOD value is in the fourth location, and the lowest one is in the first location. Based on Government Regulation of the Republic of Indonesia No.82 of 2001, DO quality standards for class II are compatible between 3-6mg/L. Decomposition of organic matter by microorganisms requires dissolved oxygen (Tontowi, 2002). Therefore, lower DO levels will increase BOD levels in the water.

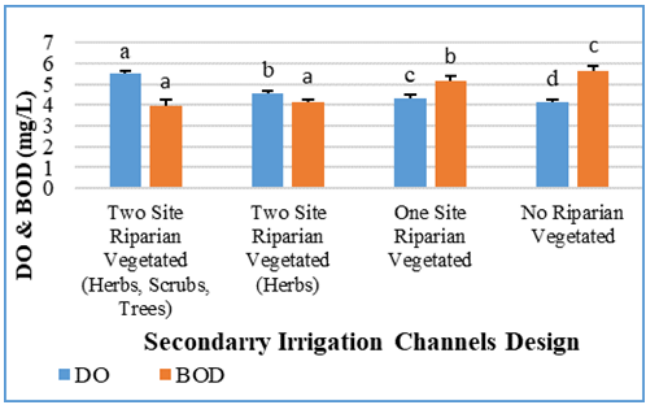

Figure 6. DO and BOD values in four secondary irrigation channels design

3.3. Interaction of Riparian Vegetation and Water Quality in Four Types Secondary Irrigation Channels at Slamet Village, Malang Regency

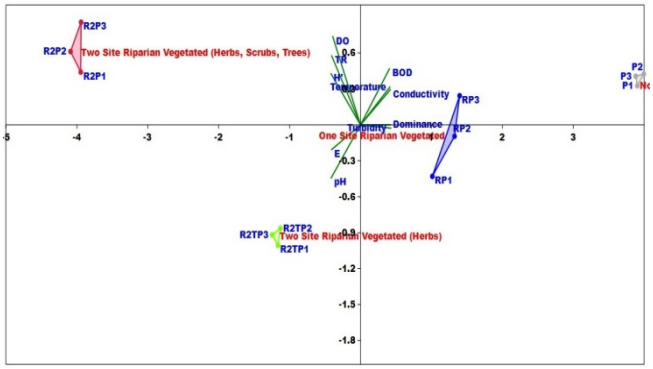

Figure 7. Characteristics profile in each locations based on riparian vegetation and water quality

Based on Figure 7, it can be seen that secondary irrigation channels with four different riparian types have an influence on the physical chemical water quality. The results of riparian vegetation profiles and water quality indicate that each location has different characteristics. This can be seen based on cluster and biplot analysis. Based on cluster analysis, there are four sub-groups. However, irrigation with two side riparian vegetation and trees combination has almost the same characteristics with two sides riparian vegetation without trees combination. Whereas irrigation with one sided riparian vegetation have the same characteristics with stone wall irrigation channels. Two sides riparian type irrigation with trees and without trees is characterized by high H', *Taxa Richness, Eveness*, pH, and DO values. Riparian vegetation in one-sided and without riparian vegetation (stone walls) have high values of conductivity, BOD, turbidity and Dominance. It shows that in irrigation channels with lower riparian vegetation it has low water quality.

4. Conclusions

Irrigation channels with two sides riparian vegetation and trees have better water quality than other types of the irrigation channels. This is indicated by the high value of taxa richness (42 herbs species), H' index (5.12), *evenness* (0.95), DO (5.49) and low of a dominance index (0.03). Irrigation channels without riparian vegetation have low diversity and DO index. However, based on Government Regulation of the Republic of Indonesia No.82 of 2001, the water quality of the four types of irrigation channels still meets the quality standards of class II. Therefore, it can be concluded that the profile of riparian vegetation indirectly correlates with water quality.

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