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Research Article

Evaluation of water quality due to the use of intensive fertilizer on farmer level in the upstream of Bedadung Jember Watershed, East Java, Indonesia

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Abstract: Upstream cultivation activities by use intensive fertilization have an impact on water quality degradation. Accumulation within several decades will cause damage to the hydrological conditions the watershed. Residual substances and heavy metals due to intensive fertilization will affect the biotic and abiotic components of the watershed ecosystem. Water in Indonesia is divided into several classes, namely class I, II, III and IV. Every class has a quality standard according to its designation class. This study aimed at evaluating the status of water quality based on physical and chemical parameters in the upstream area (rainfall catchment). Water sampling was carried out at three points, namely water sources (in), locations of aquaculture activities (irrigation), and rivers (out). Chemical parameter results showed that DO was 7.16 mgO_2/ L in the river (out), BOD was 7.84 mg/L in irrigation, COD in the river was 25,50 mg/L, the irrigation point nitrate was 6.75 mg/L, and pH average was 6.80 almost at each sample point. As for the physical parameters consisting of colour, smell, and temperature. The physical parameters based on Government Regulation No. 82/2001 were still in accordance with the specified quality standards. Management through monitoring river water quality requires an integrated model as an effort to conserve water resources. Result Rapid Rural Appraisal in the upstream area of the Bedadung Jember watershed showed that the role of institutions at the farm level was less than optimal. Communication between farmers level, agricultural extension workers, and several stakeholders was not good. Meanwhile, the participation of the community and several stakeholders had an important role as users of natural resources in conservation.

Keywords: *conservation, ecology, lands, model natural resources, watershed*

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Introduction

A few years ago, in the middle area (urban) of the Bedadung river have been contaminated by heavy metals and decreased biodiversity of the biotic components in the watershed. Water quality is below the quality standard (Munandar and Eurika, 2016). It is due to high intensive agricultural activities on cultivated plants in the upstream watershed (Alfarisy, 2018). Fertilization is one part of intensive agriculture, and if uncontrolled will cause ecological damage in the watershed system (Nangia et al., 2010; Kourgialas et al., 2017; Yanmei. Li et al., 2017; Hensley et al., 2020). Intensive fertilization is also influenced by the type of cultivated plants like food plants, which require more fertilizer than plantation crops (Liu et al., 2019; Qi et al., 2020). The accumulation of excessive use of fertilizers will cause heavy metals in water and other river biotic components, so the use of macro fertilizers should be considered because these elements are also available in the soil (Lundy et al., 2012; Whitacre, 2015; Younas et al., 2017; Younas et al., 2017; Wei et al., 2018; Li et al., 2019; Zhou et al., 2020).

Intensive agricultural activities in the upstream reaches of the watershed must be balanced with conservation activities so that the preservation of nature is maintained. Natural resources found in parts of the forest can be utilized but also require ecosystem balance. So there is the value of environmental economic services to balance the exploitation of forest resources with conservation activities. One example of the value of environmental services that have been applied in Indonesia in efforts to manage natural resources in the catchment area is the use of hydropower plants in West Sumatra (Yonariza et al., 2019). In the upstream reaches of the Bedadung river, it has not been able to identify the value of environmental services that can be implemented in the context of conservation of water catchment.

A catchment area is a location a process of infiltration of rainfall from the hydrological process to be absorbed and flowed in the middle to downstream (Burton, 2003). The area is an upstream watershed that is identical to the diversity of forestry trees. In the other hand, to the headwaters of the Bedadung River, some areas have been turned into paddy fields for planting food crops and plantation. Farmers focus more on yields without considering environmental balance. So that the potential for erosion and morphological watersheds (Aschonitis et al., 2011; Fenta et al., 2016). Potential erosion will cause a decrease in the quality of land-use and sedimentation (Mai et al., 2013; Nyangon et al., 2019). Several approaches are needed in identifying and assessing impacts that will occur when experiencing watershed morphological and physiological changes (Tiwari et al., 2009; Palsaniya et al., 2012; Palsaniya et al., 2012; Altaf et al., 2014; Andriyani et al., 2019).

The purpose of this study was to evaluate the status of upstream water quality due to intensive use fertilizers. Water quality status determines the steps for treatment as integrated water resource management. In Indonesia, efforts to conserve water resources have been regulated in Government Regulation No. 37 of 2012 concerning integrated watershed management. The status of water quality in Indonesia is divided into several clusters or classes based on its designation, which has also been regulated in Government Regulation No. 82 of 2001. Conservation efforts in the catchment area are prioritized by balancing the use of fertilizers wisely so as not to damage the quality and quantity of water. Unwise use of fertilizers will have an impact on soil and water damage (Liu et al., 2019; Mohammadi et al., 2019; Li et al., 2020).

Materials and Methods

Location of research and typology

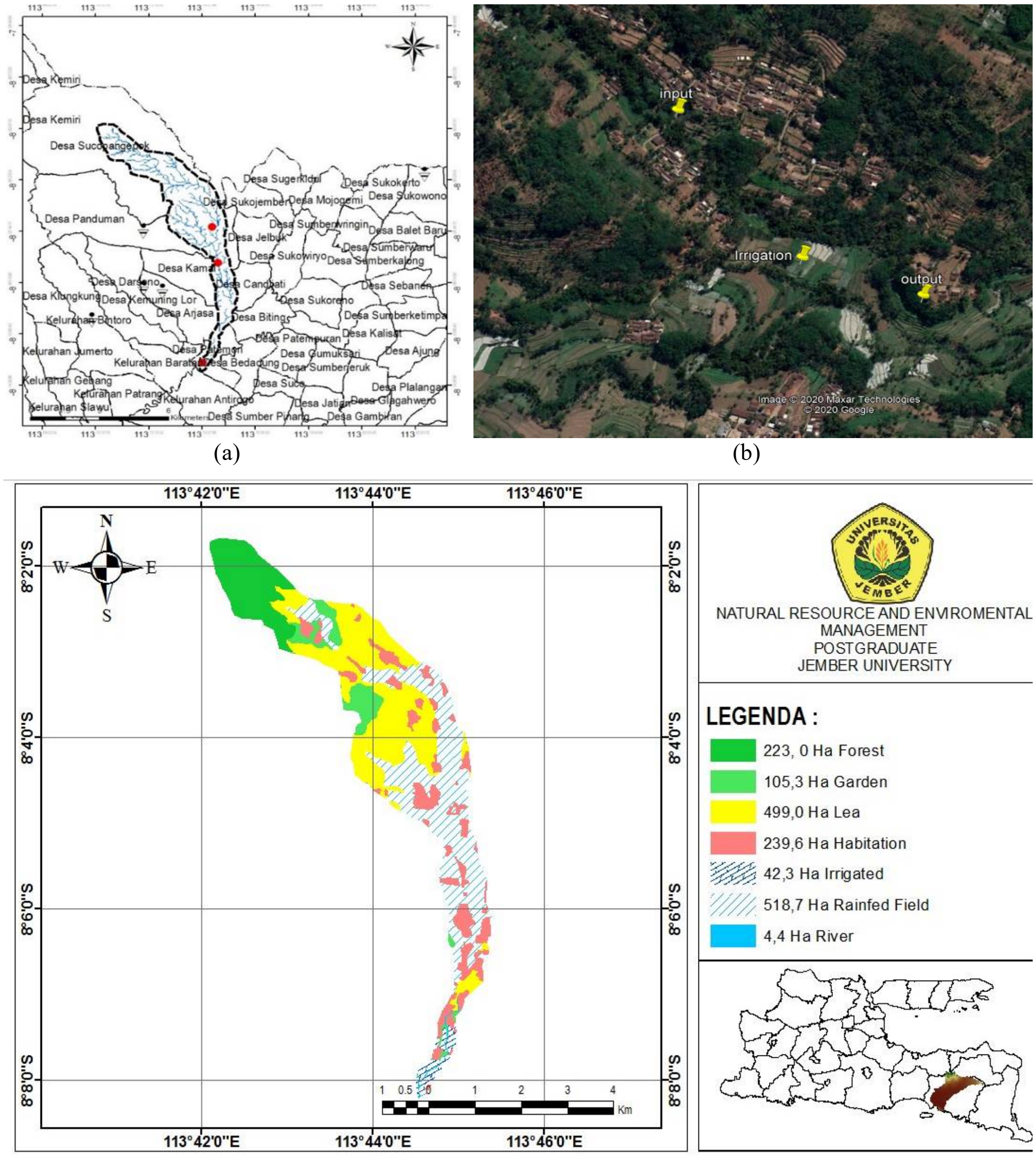
The research was conducted at a water catchment area in the upstream Bedadung River Basin on the border of the forest, and rural area is Sucopangepok Village, Jember, East Java, Indonesia. The area is located at Latitude 8°3'10.82"S and Longitude 113°44'14.22"E. Sucopangepok Village is upstream watershed from Bedadung River and becomes the source of water for downstream urban areas such as agriculture, fishery, domestic, and industry. One of the areas has a direct border with Argopuro Mountain. The location has elevation 600 above sea level. Choosing the status of the water was taken from the cultivation activity on the farmer in the upstream area (Figure 1). Table 1 presents the characteristic typology of how viewing agriculture system in the upstream watershed.

Table 1. Typology in the upstream area.

Variable	Description	Unit
Total respondent	60 respondents	People
Fertilizer	Urea, Ponska, ZA, and Kaltim	kg/ha/time period
Topography	Slope (9-15) Slightly	%
Water resources	Irrigation and water source	-

Sampling of water and design

Water sampling was carried out at three points, namely the upstream, middle and downstream areas by referring to the Water Monitoring Standards in Watersheds (Rahayu, 2009). The upstream area or water source (in) is the source water area which is located in a forest area, while the middle area is the location of rice fields or irrigation to flow through crops (rice, tomatoes, chilies, and eggplants). At the downstream (out) is a river area that has been drained by water from crop cultivation or irrigation activities.



(a) (b) (c)

Figure 1. Location of research (a), sampling water (b), and land-use on the upstream watershed (c).

Figure 2 shows the adoption of a schematic illustration in watersheds (Loucks et al., 2005; Zoga et al., 2012). The measurement of the intake of water was done by grab sampling. Each point was taken as many as two samples with a volume of one litre. Samples of collected water were stored in cool boxes and analyzed in the Laboratory. Water sampling was carried out in the rainy season when farmers were planting cultivation crops.

Parameter of water quality

Water quality observation consisted of physical and chemical observations (Table 2). The physical observations were made directly at the research location using specific tools, whereas chemical observations were carried out at the Laboratory of PT. Jasa Tirta II Malang, which is a state-owned company that focuses on managing and monitoring water resources in Indonesia.

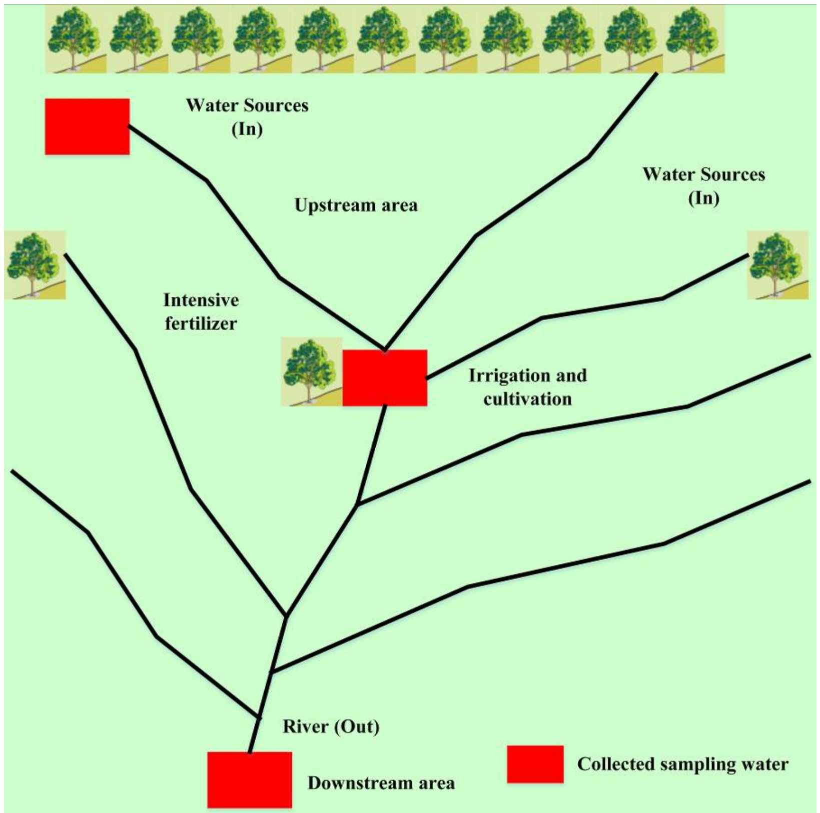


Figure 2. Sampling water on research location at sub-watershed.

Table 2. Parameter and analysis method water quality have observed.

Parameter	Characterization	Unit	Analysis Method
DO (Dissolved Oxygen)	Chemical Organic	mg O_2/L	QI/LKA/02 (Electrometry)
BOD (Biological Oxygen Demand)	Chemical Organic	mg/L	APHA.5210 B1998
COD (Chemical Oxygen Demand)	Chemical Organic	mg/L	QI/LKA/19(Spectrophotometry)
Nitrate (NO_3^-)	Chemical Organic	mg/L	QI/LKA/65
pH	Chemical Organic	-	pH meter
Colour	Physic	-	-
Temperature	Physic	^{O}C	Thermometer

Reference of water quality on conservation in Indonesia

Conservation activities referred to in Government Regulation No. 37 of 2012 concerning conservation integrated watershed management are intended to manage water resources in terms quality (Table 2) as justification according to their intended use. Table 3 is the minimum standard that must be achieved in monitoring water quality, especially in river areas for agriculture. The parameters in Table 3 are the national water quality standards, but in this study, only a few parameters were observed to focus more on the impact of fertilization on priority parameters in monitoring water quality.

Concept model on conservation offered

The concept presented in Figure 3 is the result of schematic adoption in the watershed management model (Loucks et al., 2005) which has been refined with a flow chart of the current conditions of the Bedadung River due to intensive agriculture, the impacts that occur, and related to the behaviour of farmers in using fertilizer.

Table 3. Criteria quality of water based on allocation.

Parameter	Unit	Class				Information	Information
		I	II	III	IV		
Physical							
Temperature	^{O}C	Deviation 3	Deviation 3	Deviation 3	Deviation 5	Deviation existing	Class I: focus on drinking water and domestic
Dissolved residue	mg/L	10^3	10^3	10^3	10^5		
Suspended residue	mg/L	50	50	400	400	Management for water conventional <500 mg/L	Class II: focus on agriculture (irrigation) and fisheries
Chemical							
pH		6-9	6-9	6-9	5-9		Class III: agriculture, plantation, irrigation
BOD (Bio Oxygen Demand)	mg/L	2	3	6	12		
COD (Chemical Oxygen Demand)	mg/L	10	25	50	100		
DO (Dissolved Oxygen)	mg/L	6	4	3	0		
Total Phosphate	mg/L	0,2	0,2	1,0	5,0		Class IV: tourism
NO_3^-	mg/L	10	10	20	20		
NO_2^-	mg/L	0.06	0.06	0.06	(-)		
Microbiology							
Total coliform	number/ 100 mL	10^3	$5x10^3$	10^3	10^3		

Source: Peraturan Pemerintah No. 82, 2001.

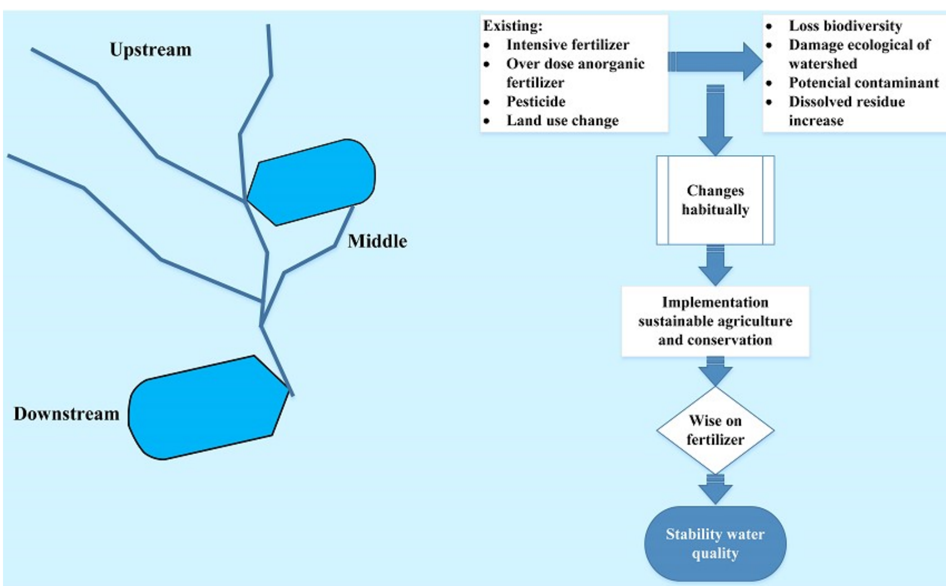


Figure 3. A simple model for creating good water quality on a watershed.

The simple concept presented in Figure 3 shows that fertilization is balanced with conservation in accordance with the conditions of the region will cause a balance of watershed ecosystems and stability of water quality so that the sustainability of integrated watershed management can be implemented at the farm level. Some information related to the reasons why farmers use excess fertilizer is identified by RRA (Rapid Rural Appraisal) (Henman and Chambers, 2009; Jensen, 2010; Fredudenberger, 2010).

Results

Status of water quality

Figure 4 shows that water quality with DO (Dissolved Oxygen) in the sources of water (in) and irrigation tended to be the same. DO is the amount of oxygen available in a body of water. During the flow process, DO water was relatively the same starting from the time the water is in the source to the irrigation location. This was influenced by topographical conditions. Water flowing from the source to the potential irrigation was not so high that the movement of water tended to be stable. U1 and U2 are water sample codes with 1 and 2 repetitions. DO average in the source area was around 6.85 mgO_2/L, but the DO value was different when arriving at the river point (out), the DO value at each replication was somewhat different, namely 8.30 mgO_2/L and 7.90 $mgO_2/$ L and the average was 7.60 mgO_2/L. The difference in value was observed when water sampling was done at a different point by looking at the end of the irrigation point. On the river, there are creeks with different heights. Figure 5 shows that the BOD value of the irrigation point was higher than the in and out points. This is because at the point of irrigation fertilization activities occurred so that the need for oxygen to break down high solutes. At the point irrigation, BOD values reached 7.84 mg/L (U1) and 6.47 (U2), so the average was 7.16 mg/L. The river (out) COD value was higher compared to water sources (in) and irrigation points (Figure 6). At U1, the COD value in the river (U1) was 26, 36 mg/L and (U2) was 24.63 mg/L, then 25.50 mg/L was average. This is because dissolved chemicals that are difficult to break down so that they gather at the point of the river. In Figure 7 the highest nitrate concentration of fertilization was located at the irrigation point with a value of (U1) 6.87 mg/L and (U2) 6.63 mg/L, so that average value of the nitrate was 6.75 mg/L. Based on Table 3, the nitrate values were still in a secure condition (in accordance with specified quality standards).

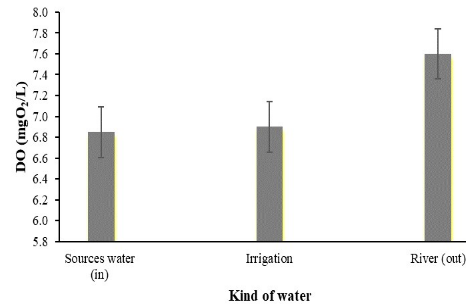


Figure 4. DO parameter.

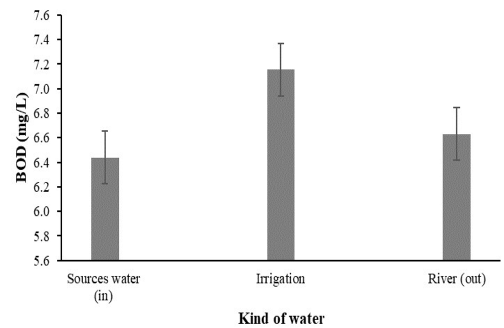


Figure 5. BOD parameter.

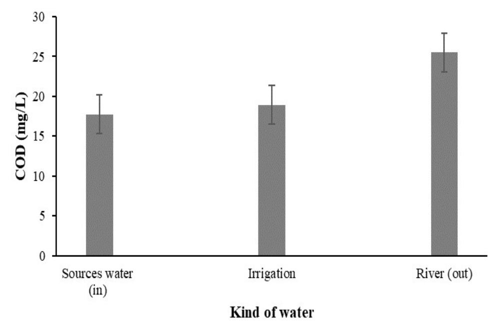


Figure 6. COD parameter.

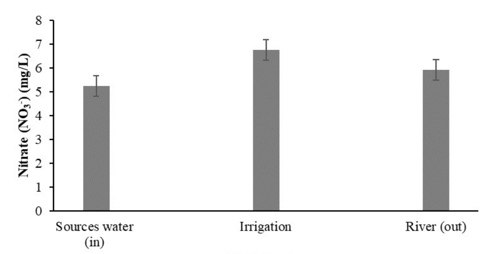


Figure 7. Nitrate parameter.

Figure 8 shows that the pH of water in the upstream watershed was still in a secure state. The pH at the point of water sources in (in), irrigation, and rivers (out) was almost the same, 6.80. As for the physical parameters (Table 4) that were carried out directly at the study site, the colour of the irrigation section was clean and slightly turbid, while the points in and out were clean and turbid free. For scents at all three points were free from odours that contained fertilizer residues, while water temperature conditions were relatively secure with a standard deviation of three. At the point of water source (in) the water temperature was lower than the point of irrigation and river (out).

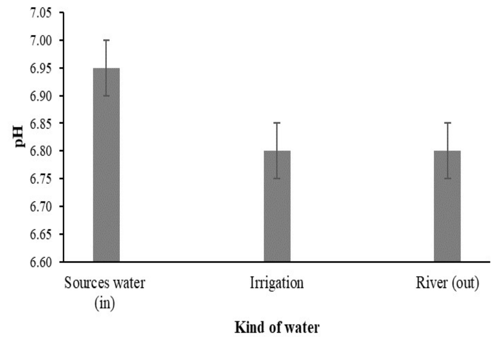


Figure 8. pH parameter.

Table 4. Physical parameter observed on water.

Parameter	Characterization	Plot of Sampling	Information
Colour	Physic	Sources water (in)	Clean Clean
		Irrigation	Clean, Turbid Clean, Turbid
		River (out)	Clean Clean
Smell	Physic	Sources water (in)	Unsmell Unsmell
		Irrigation	Unsmell Unsmell
		River (out)	Unsmell Unsmell
Temperature	Physic	Sources water (in)	Deviation 3 18°-24 °C 20 °-26 °C
		Irrigation	Deviation 3 22 ° -28 °C 22 ° -28 °C
		River (out)	Deviation 3 22 ° -28 °C 22 ° -28 °C

Recommendation model for water conservation

After identifying and assessing water quality status, efforts are needed to determine the ideal conservation model based on the results of the analysis and regional conditions. Improving the quality and quantity of river water requires support from various parties, namely stakeholders and the active role of farmers or the community. The form of farmers' participation in efforts to conserve water resources contributes significantly to the sustainability of natural resources in the upstream region. So based on available data, planning and management of water resources is needed to reach the equilibrium point. The use of fertilizer in intensive agriculture is more to be considered, so it does not pollute the environment, which affects water quality. The adoption of Loucks et al. (2005) was perfected by characterization and typology of the area so that a sustainable integrated water resources management model can be formed (Figure 9).

Discussion

Status determining conservation

Management of water resources in Indonesia based on Government Regulation No. 82 of 2001 regarding the standard quality of water allotment based on its function is the target in managing and using water wisely.

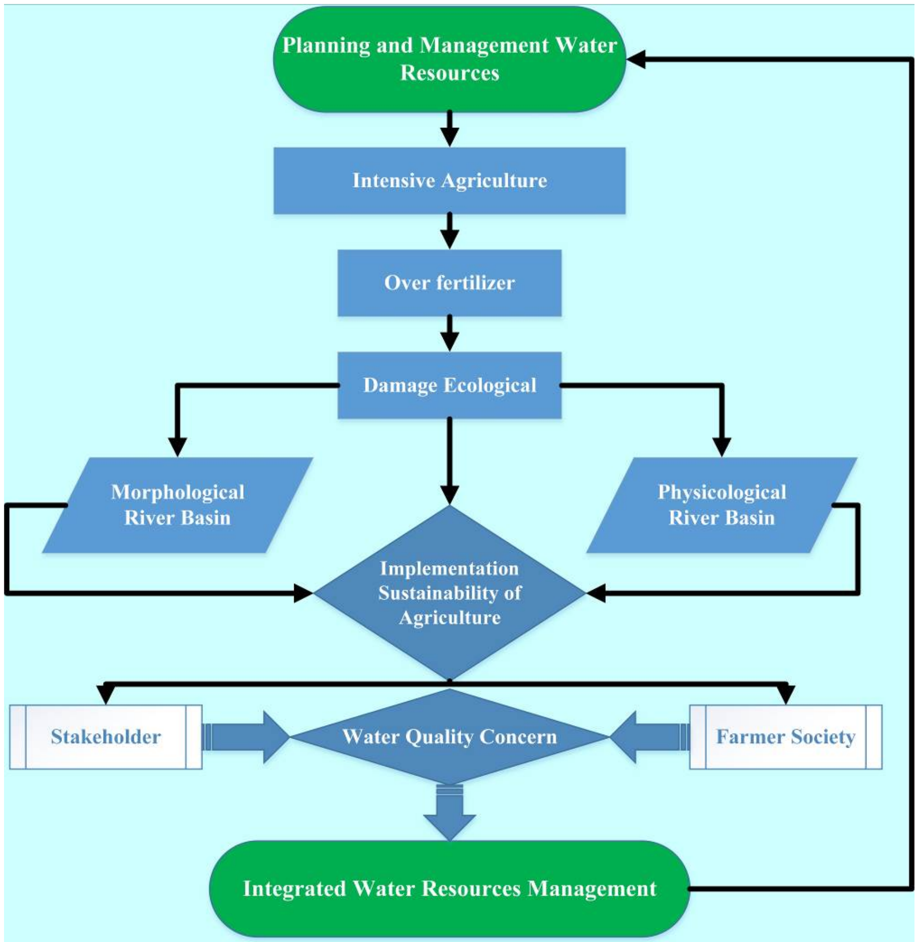


Figure 9. Model for integrated water resources on the river basin level.

Therefore, efforts are needed to stabilize the condition of the water so that when it is used, it does not have a detrimental impact. Based on the results of research of Munandar and Eurika (2016), the assessment of water quality in the middle can be judged to be less than the specified quality standard. The results of the summary of water quality by referring to Table 2 there are several parameters that must be considered so that it is feasible to use. In this study, the status of water is more focused on agricultural water needs. However, studying water cannot be limited to interests and territories only, but in the middle and downstream, the status of water determines eligibility in its use. The challenge of conservation in the upstream reaches is the main focus in balancing the quality of water so as to avoid harmful residues and heavy metals. Government Regulation Number 37 of 2012 concerning the conservation of watershed management must be carried out in an integrated manner. Conservation efforts aim to restore water so that food and ecological security in a watershed is maintained. Conservation efforts involve various parties ranging from stakeholders and users from the local area and those who use it. Managing natural resources is a joint task to realize sustainable development.

BOD and COD parameters referring to Table 2 with the class 2 category concluded that they exceeded the specified quality standard. Water quality status in class 2 is intended for agriculture and fisheries areas. BOD and COD are parameters related to residues that are difficult to decompose. The residue generated can be from fertilizers and pesticides so that when in water it takes time to be reduced (Wang, 2012; Younas et al., 2017; Qi et al., 2020; Zhang et al., 2020; Nangia et al., 2020). In addition, residues that are difficult to reduce will cause biotic components such as algae and others to be threatened. The presence of biotic components in water helps in decomposing residual substances based on their respective roles (Lundy et al., 2012; Aschonitis et al., 2012; Yanmei Li et al., 2017; Liu et al., 2019; Li et al., 2019; Hensley et al., 2020). Data presented in Figure 7 show that the nitrate parameter was still in a secure situation, but the value of the analysis results was close to the standard. The existence of nitrate should be anticipated, so it does not pollute the environment (Nangia et al., 2020; Lee et al., 2020; Wang et al., 2020). The presence of nitrate can be identified by the isotope $\delta^{15}\delta\text{-}^{18}O$ ever done on the river Kelan, China (Jin et al., 2020; Yi et al., 2020).

The RRA (Rapid Rural Appraisal) was conducted on farmers in the upstream watersheds regarding why fertilizer is used intensively (not following recommendations). Reasons obtained that by using more fertilizers, the growth of plants will be faster, and the yields obtained will be following the wishes of the farmers. Farmers still do not know the concept of the use of fertilizers scientifically. There are several factors concerning why farmers do not know the principles of fertilization in the upstream of the institutional Bedadung Jember watershed. Farmers do not apply fertilizers optimally, the amount of fertilizer is limited, local agricultural stakeholders and extension agents are lack of coordination; hence farmers do the right thing based on hereditary knowledge of ancestors. The role of farmer institutions is very important concerning water conservation (Juliana, 2015; Ntanos et al., 2018; Lefkeli et al., 2018). For example, such as the Atchafalaya River to decompose nitrates using several ecological components ranging from riparians and some organic material (Mittelstet et al., 2019; Lee et al., 2020) and in China using SWAT tools in determining BMP (Best Management Practice) with climate change scenario (Qiu et al., 2020). The approach with the above models is one example of efforts to conserve water resources at the farmer level in the upstream watershed.

Implementation for to conservation of natural resources

Internationally in the management of integrated water resources, there are several principles ranging from economics, justice, and sustainability. They are then arranged in the form of a structure that includes management instruments, environmental regulations, and regional administration (border administration) to create a balance of water or water as natural resources (Hassing et al., 2009). As an effort to manage and regulate water resources, planning and implementation of integrated watershed management are needed (Burton, 2003; Global Partnership, 2009). The above water resource management model at the river level can be adopted in several aspects according to the typology and characteristics of the Bedadung River Basin.

The success in implementing a model is inseparable from the role of farmers and coordination with stakeholders in efforts to achieve water stability through conservation. It will not work if there is no role and participation of the community in the implementation of an integrated management model. The existence of farmer institutions is essential in supporting sustainable water. According to (Ntanos et al., 2018), education and motivation support in farmer institutions through environmental schools can change the behaviour of farmers related to agricultural knowledge such as the principle of fertilization. Then through environmental schools can bring up socio-culture in carrying out environmental conservation efforts (Lefkeli et al., 2018). These efforts can be adopted in increasing farmer institutional empowerment so that they can implement the concept of sustainable agriculture. For example, in Rwanda, farmers are equipped with knowledge of soil science in conservation activities by being given knowledge and training on the wisdom of using fertilizer (Rushemuka et al., 2014).

The concept of sustainable agriculture is an ecological-based farming system. So that when farmers' insights and knowledge increase, they can run the model. A simple example that can be done is to start switching from the use of inorganic fertilizers to organic fertilizers. The use of organic fertilizer is much better because it does not pollute the environment, but can increase soil fertility (Singh, 2012; Zhang et al., 2020). These activities have fulfilled the implementation of the model in integrated management of bases.

Conclusion

The focus of this research assessment was the status of water quality in the upstream part of the catchment area. The upstream conservation area had been turned into paddy fields and fields so that intensive fertilizer use had an impact on water quality degradation. The results of the assessment on the BOD and COD indicators were below the quality standard set in class II. Hazardous residue substances from fertilizers are difficult to decompose. So it requires conservation efforts in restoring water quality. Not only that, the level of farmers still can not understand the rules in fertilization. An important point of this research is the status of water quality in the catchment area is the main picture in determining the conservation efforts that must be done. The recommendations that can be done are: 1) provide knowledge about the principles of sustainable agriculture in paying attention to environmental aspects, especially the rules of fertilization; 2) optimizing the role of farmer institutions at the farm level in supporting the role of participation and coordination between farmers and stakeholders; 3) together in formulating a simple model based on characterization and typology of the region as an effort to manage integrated water resources.

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