INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print), 2222-5234 (Online)
http://www.innspub.net
Vol. 14, No. 2, p. 264-272, 2019

RESEARCH PAPER OPEN ACCESS

# Evaluation of land use impact on soil and water quality degradation in Santan and Marangkayu Wathershed

**Akhmad Sopian[1,2], Sigit Hardwinarto[2], Marlon Ivanhoe Aipassa[2], Sumaryono[2]**

[1]*Agrotechnology Program, University of Widya Gama Mahakam Jl.K.H Wahid Hasyim Sempaja Samarinda. 75124Indonesia*

[2]*Forestry Science Doctoral Program, Forestry Faculty, University of Mulawarman Samarinda, Jl.Gunung Kelua, Kampus Unmul, Samarinda ,Indonesia*

**Key words:** Degradation, Pollution, Watershed, Marangkayu, Santan.

http://dx.doi.org/10.12692/ijb/14.2.264-272 Article published on February 27, 2019

## Abstract

Watersheds in Santan and Marangkayu are involved in Kutai National Park area as a conservation forest area. The forest area is decreasing due to illegal logging, forest clearing, mining, plantation and agriculture. The changing of land use which not followed by preventing steps causes degradation. Hence, this study aims to figure out the level of land degradation to determine the appropriate conservation direction to make the land use sustainable. This study applied USLE equation to predict soil erosion rate, Geographical Information System (GIS) to determine critical land through overlay analysis, and STORET method to measure the water quality index. The result shows that the danger level of erosion in Marangkayu watershed is higher than in Santan watershed. Land degradation caused by mining activity raises critical land and contaminated water. Index of land closure is about 69%, which is still suitable as buffer zone for Santan watershed area. Meanwhile, Marangkayu watershed results 22% of land closure index which is no longer appropriate as buffer zone. This study also found that land degradation is caused by land clearing for mining, with 10.746,20 hectares of critical land in Santan watershed and 485, 83 hectares of critical land in Marangkayu watershed. In addition, the water quality of rivers in Santan and Marangkayu have low level of contamination considering the high Fe content as the result of mining activity at the river upstream. Referring to the research result, intensive forest security efforts are highly needed to prevent illegal logging, monitor activities causing expansion of open land use and critical land that also create water pollution.

* **Corresponding Author:** Akhmad Sopian ✉ sopian063@gmail.com

## Introduction

Land use commonly affects the land use planning on an area. The planning is mostly not completed with preventive acts of land damage, making the land degraded more and more which shown by high level of erosion and sedimentation and low level of rainwater infiltration. Budianto *et al.* (2018) states that the changes of land use initiate decrease of soil bearing capacity, that make the land unable to fulfil its function and then categorized as critical land. Likewise, the decrease will influence other resources, especially water resources.

Degradation on function of land in a watershed and deprivation of water resources are two main issues occurred in most of watersheds in Kalimantan. The amount and intensity of watershed are considerably decreasing year by yearthat makes more areas engulfed by drought meanwhile other areas are frequently flooded. Batistella and Valladares (2009) emphasized that the risk of land degradation as the impact of erosion increase as the result of agriculture expansion and intensification. The risk decreases when it happens on flat land which is related to the vegetation and the forest. Agriculture expansion and introduction will escalate the erosion process, leading to higher risk of land degradation.

Takamatsu *et al.* (2014) conducted an experiment on sub-watershed in Sekong, Sesan, and Srepok (called 3S), which are parts of lower Mekong River Basin, joining Cambodia, Lao People's Democratic Republic, and Vietnam. Dynamic transition of land use occurred in this area due to the fast changing in economic, people and the environment.

The changes in the use of main land involve real rainforest deforestation, expansion of agricultural land and urban area, and commercial plantation such as rubber tree. The land use transformation has an effect on local and regional hydrological processes, resulting scarcity of water flow during drought and flash flood, as the effect of deforestation.

Located in three regencies namely East Kutai, Kutai Kartanegara, and Bontang, Watersheds in Santan and Marangkayu have important role in supporting carrying capacity of surrounding environment. However, there are two problems commonly encountered in these watersheds, specifically, 1) flooding, which is pretty often happened during rainy season, and 2) land clearing, which not considering principles of land and water conservation as well as environmental sustainability.

At recent condition of land closure around the watershed, there are somewhat wide shrubs due to land clearing as a result of coal mining activity and plantation. The shutdown of primary forest turned the forest into secondary one, causing simultaneously expansion of open and critical land, which then affect the natural resources and water pollution.

In addition, to examine land degradation, this research applied three approaches, to be exact, 1) danger level of erosion by using USLE equation, 2) critical land by applying geographical information with map overlay, and 3) quality of river water by applying index analysis of water pollution with STORET method. Furthermore, this study aims to investigate the transformation of land use and to identify the correlation between the land use transformation and water quality. This study is also expected to encourage efforts for preventing land degradation.

## Materials and methods

Parametric analysis was conducted to predict the level of soil erosion by using equation of USLE (Universal Soil Loss Equation), as follows:

$$A = R \times K \times L \times S \times C \times P$$

The danger level of erosion is determined by using metrics, i.e.; combination between score of annual rate soil erosion prediction and depth level of soil solum.

To determine the critical land, the researcher applied geographical information system (SIG) through overlay analysis by using thematic maps from factors of critical land determiner.

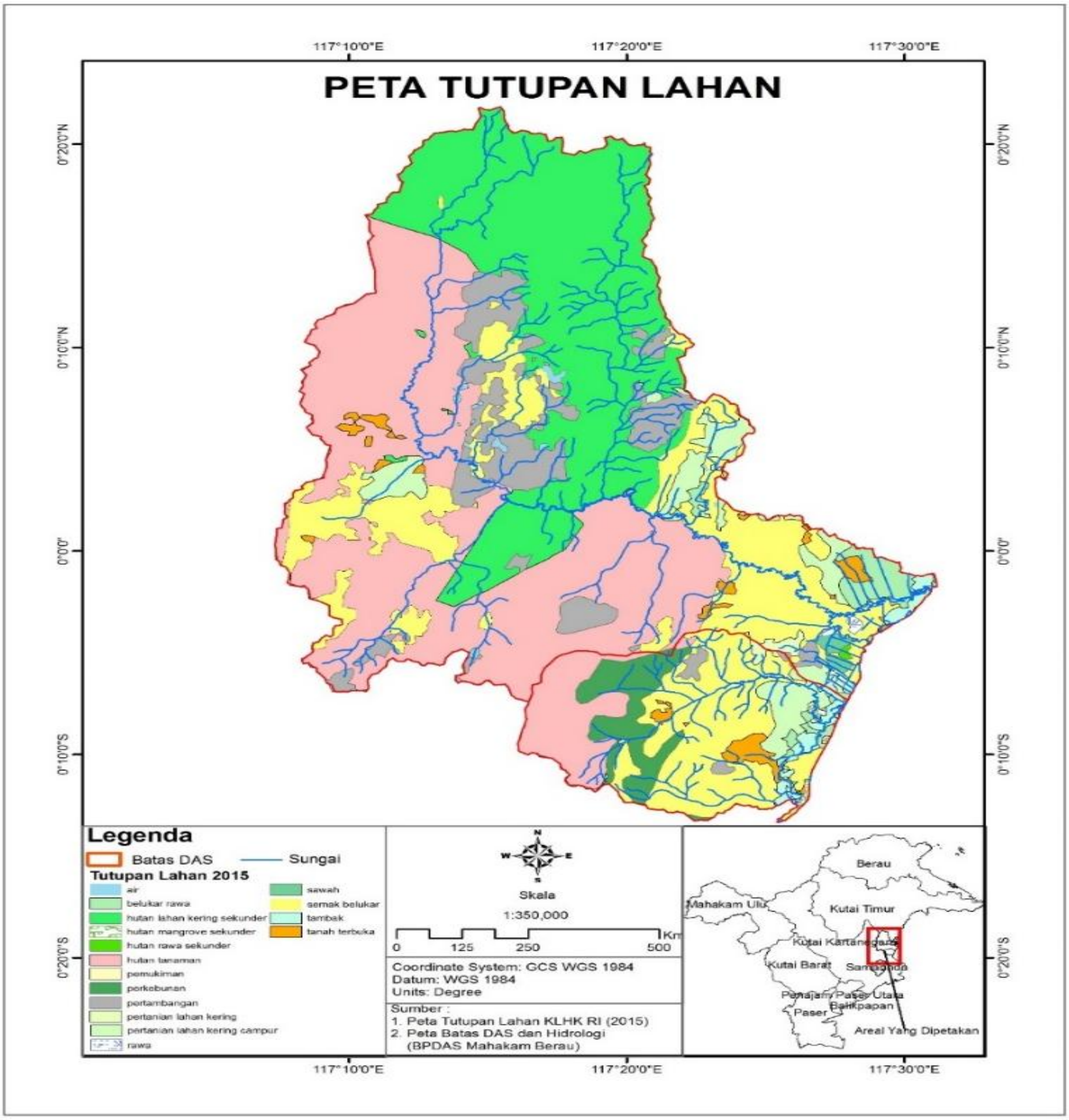


**Fig. 1.** Map of land closure in watersheds at Santan and Marangkayu.

The land closure as critical land determiner is measured based on the level of closing density, especially on types of vegetation that protect land from erosion threat.Furthermore, the other determiner factors, such as slope, type of soil, and rainfall were measured based on their sensitivity and intensity.

Critical land determiner can be categorized based on the calculation of scales from each factor, as the following:

Critical Land = Land Closure + Slope + Type of Soil + Rainfall

From the calculation, it is reached the maximum score is 19 for critical area and the minimum score is 4 for non-critical area. The classification of critical area is divided into five classes.

The water quality status is determined based on STORET method or index of water pollution referring to Decree of the Minister of Environment No.115 / 2003 about guidelines for determining water quality status, i.e.: using scoring system based on US-EPA (Environmental Protections Agency) with class II classification of water quality. The formula used for examining index of water quality is as the following;

$$PIj = \sqrt{\frac{(Ci/Lij)^2 M + (Ci/Lij)^2 R}{2}}$$

Wherein;

PIj = Index of Water Pollution

(Ci/Lij) M = Maximum score of Ci/Lij

(Ci/Lij) R = average score of Ci/Lij

Standard of water quality is determined based on the following criteria:

$0,0 \leq PIj \leq 1,0$ =fulfil the quality standards, good condition

$1,0 < PIj \leq 5,0$= lightly polluted

$5,0 < PIj \leq 10$=medium polluted

$Pij > 10$ =highly polluted

## Result and discussion

*Danger level of erosion*

The levels of erosion danger in Santan watershed are 4.6% at high category, 14% at very high category and 20.3% at medium category, 40.7% at low category, and 20.4% at very low category. In brief, the danger level of erosion in Santan watershed in considered low, making up 61.1%. Meanwhile, in Marangkayu watershed, the danger levels of erosion are 19.5% (high category), 15% (very high category), 42.8% (medium category), 14.2% (low category) and 8.4% (very low category).

**Table 1.** Determiner Factor, Criteria, and Critical Land.

| No. | Determiner Factor | Description | Criteria | Scale |
|---|---|---|---|---|
| 1. | Sensitivity | 0 – 2 % | Flat | 1 |
| | | >2 – 15 % | Sloping | 2 |
| | | >15 – 40% | A bit steep | 3 |
| | | > 40 % | Steep | 4 |
| 2. | Type of soil | Alluvial, Gleiosol | Not Sensitive | 1 |
| | | Cambisol | Quite Sensitive | 2 |
| | | Podsolic, Ocsisol (Latritic) | Sensitive | 3 |
| | | Regosol, Lithosol, Organosol | Very Sensitive | 4 |
| 3. | Rainfall | 2500 – 3000 mm/th | Low | 1 |
| | | 3000 – 3500 mm/th | Medium | 2 |
| | | 3500 – 4000 mm/th | High | 3 |
| | | > 4000 mm/th | Very High | 4 |

*Source*: BAPLAN (2004).

It can be said that Marangkayu watershed has medium danger level of erosion. Concisely, the data shows that the erosion danger level at Marangkayu watershed is much bigger than in Santan watershed. The danger level of erosion at both areas is displayed in table 2.

The high level of erosion danger in this research setting is caused by the sloppy and hilly land with steep topography making the land prone to erosion. In Santan watershed, 50% of the area is at a slope of more than 15% to 40%. Meanwhile the other 30% area is at a slope of more than 40%. On the other hand, 55% of Marangkayu area is at a slope of more than 15% to 40% area, and the other 27% is at a slope of more than 40% (See Figure 1).

The figure shows the significant correlation between land slope and danger level of erosion. Arsyad (2010) stated that slope and length of hill are two characters of topography that strongly influence surface flow and erosion. The steeper the hill is, the faster the surface flow is, resulting larger lifting energy of surface flow. Moreover, combination between infrequent vegetation and high intensity of rainfall initiates high erosion rate, even at flat areas. Therefore, the high erosion threats occur in wet tropics where the vegetation has vanished.

**Table 2.** The area width of watersheds Santan and Marangkayu based erosion danger level category.

| Area of Watershed | Erosion Danger Level Category | Width (hectares) | Percentage (%) |
|---|---|---|---|
| Santan | 0-SR (very low) | 25,476 | 20.4 |
| | I-R (low) | 50,904 | 40.7 |
| | II-S (medium) | 25,327 | 20.3 |
| | III-B (high) | 5,707 | 4.6 |
| | IV-SB (very high) | 17,556 | 14.0 |
| | Total | 124,970 | 100.0 |
| Marangkayu | 0-SR (very low) | 2,059 | 8.4 |
| | I-R (low) | 3,478 | 14.2 |
| | II-S (medium) | 10,475 | 42.8 |
| | III-B (high) | 4,777 | 19.5 |
| | IV-SB (very high) | 3,674 | 15.0 |
| | Total | 24,463 | 100.0 |

*Critical land*

Related to critical land, Santan watershed area is consisted of 40.909,68 hectares (33%) considered not too critical, 13,894.22 hectares (11%) in critical category, 50,928.15 hectares (41%) in medium category and 19,042.22 hectares (15%) in stable category. The critical land is in form of plant forest vegetation, mining area, and open space.

**Table 3.** Land area based on critical land classification in watershed Santan.

| Land Closure | Sloping | | | | Grand Total |
|---|---|---|---|---|---|
| | <2% | >2-15% | >15-40% | >40% | |
| Somewhat not critical | 2,001.83 | 6,438.18 | 17,842.00 | 14,627.67 | 40,909.68 |
| - Secondary dry land forest | | 887.72 | 17,370.43 | 12,793.30 | 31,051.46 |
| - Plantation Forest | 739.36 | 4,976.15 | 332.10 | | 6,047.62 |
| - Resident settlement | 3.05 | | | | 3.05 |
| - Plantation | | | 6.29 | 31.08 | 37.38 |
| - Dryland farming | 15.81 | 51.77 | | | 67.58 |
| - Mixed dryland farming | 721.00 | 522.54 | 133.16 | | 1,376.71 |
| - Scrubland | | | | 1,803.29 | 1,803.29 |
| - Open land | 522.61 | | | | 522.61 |
| Critical | | 261.38 | 4,971.56 | 8,661.28 | 13,894.22 |
| - Plantation Forest | | | | 2,552.59 | 2,552.59 |
| - Mining | | 45.76 | 4,607.08 | 6,093.35 | 10,746.20 |
| - Open land | | 215.62 | 364.48 | 15.33 | 595.43 |
| Medium | 116.82 | 5,825.42 | 32,741.07 | 12,244.84 | 50,928.15 |
| - Secondary dryland forest | | | | 8,651.05 | 8,651.05 |
| - Plantation forest | | 4,676.97 | 31,799.86 | 1,899.15 | 38,375.97 |
| - Mining | 2.29 | 213.06 | | | 215.35 |
| - Dryland farming | | | 247.67 | 18.51 | 266.18 |
| - Mixed dryland farming | | 907.37 | 676.99 | 1,676.13 | 3,260.49 |
| - Open land | 114.53 | 28.03 | 16.55 | | 159.10 |
| Not critical | 3,654.67 | 3,960.87 | 8,067.06 | 3,359.62 | 19,042.22 |
| - Dryland farming | 103.44 | | | | 103.44 |
| - Scrubland | 3,551.23 | 3,960.87 | 8,067.06 | 3,359.62 | 18,938.77 |
| Grand Total | 5,773.32 | 16,485.86 | 63,621.68 | 38,893.42 | 124,774.27 |

Plantation forest located at a slope of > 40% with cambodia soil type is categorized medium for critical land level. However, for plant forest with podzolic soil type is considered into critical category. Secondary dryland forest, plantation forest, dryland farming and mixed dryland farming with land of area of 12,244.84 hectares at a slope of > 40% are categorized into medium level that potential to be critical land. Meanwhile, scrubland at a slope of >40% is considered not critical. The result shows that critical land is significantly influenced by land closure, slope and type of soil. Referring to sensitivity analysis conducted by Prasena (2013), the research result confirms that soil properties are the most sensitive parameter in resulting run over. Land closure in form of scrubland will not become critical land although it is located at very steep slope. Dong *et al*, (2015) proved that grass vegetation reduce soil erosion from 63.90% into 92.75%, and the level of sediment transport from 80.59% into 96.17% at different slope and rainfall intensity. The vegetation area of secondary forest area and plantation forest is 86,678.69 hectares, making the index of land closure is 69%, which is still appropriate for buffer zone.

**Table 4.** Land area based on critical land classification in watershed Marangkayu.

| Land Closure | Sloping | | | | Grand Total |
|---|---|---|---|---|---|
| | <2% | >2-15% | >15-40% | >40% | |
| Somewhat not critical | 201.65 | 22.70 | 2,891.31 | 3,720.03 | 6,835.69 |
| - Plantation forest | | 16.95 | | | 16.95 |
| - Plantation | | 4.09 | 2,891.31 | 434.66 | 3,330.06 |
| - Mixed dryland farming | 117.86 | 1.66 | | | 119.51 |
| - Scrubland | | | | 3,285.37 | 3,285.37 |
| - Open land | 83.80 | | | | 83.80 |
| Critical | | 96.89 | 748.15 | 726.15 | 1,571.18 |
| - Plantation forest | | | | 255.23 | 255.23 |
| - Mining | | 6.04 | 175.32 | 304.17 | 485.53 |
| - Mixed dryland farming | | | | 42.21 | 42.21 |
| - Open land | | 90.85 | 572.83 | 124.54 | 788.22 |
| Medium | 0.15 | 906.85 | 5,490.25 | 1,361.22 | 7,751.44 |
| - Plantation forest | | 3.27 | 4,660.45 | 404.99 | 5,068.71 |
| - Plantation | | | | 888.32 | 888.32 |
| - Dryland farming | | | 106.51 | 67.91 | 174.42 |
| - Mixed dryland farming | | 896.70 | 723.29 | | 1,619.99 |
| Not critical | 736.64 | 1,155.72 | 5,163.13 | 1,192.02 | 8,247.51 |
| - scrubland | 736.64 | 1,155.72 | 5,163.13 | 1,192.02 | 8,247.51 |
| Grand Total | 938.45 | 2,182.16 | 14,292.83 | 6,999.42 | 24,405.82 |

In Marangkayu, the not-too-critical land is about 6,835.69 hectares (28%). Meanwhile, the other 1,571.18 hectares (6%) is considered critical, 7,751.44 hectares (32%) are in medium category and 8,247.51 hectares (34%) are not in critical category. The critical land is in form of vegetation of plantation forest, mining, mixed dryland agriculture and open space. About 255.23 hectares of plantation forest and 42.21 hectares of mixed dryland agriculture are critical since they are located at a slope of > 40% with podzolic soil type. However, 404.99 hectares of plantation forest, 888.32 hectares of plantation and 67.91 hectares of dryland agriculture are in medium category, that potential to be critical land when these lands are not managed properly. The location of land which is at a slope of >40% with podzolic soil type makes the land vulnerable to erosion. Nugroho *et al*, (2000) argue that the cause of critical land is the presence of human intervention in utilizing land for supporting their life need excessively that makes the land less productive and damaged, indicated by land erosion. Furthermore, Hardjowigeno (2007) emphasized that critical land is damaged land that losing hydro-orological function and economic function. In other words, the land does not have capability to manage water supply and produce water. In general, the damaged land area is the result of land use without concerning the land and water conservation.

Watershed retention is defined as endurance and conservation water conducted by the watershed to make rain drops can be held, absorbed, and saved in the ground and aquifer.

Watershed retention is influenced by the condition of land use vegetation, topography condition, soil and geology. The area of vegetation in form of plantation forest is about 5,340.89 hectares with index of land closure 22%, making the area is not suitable as buffer zone for watershed area to guarantee ideal watershed retention. Based on law number 7 years 2007 about layout, it is mentioned that at least 30% of river flow area must be allotted for forest area to assure environmental conservation.

**Table 5.** Result of Index Air Pollution in Rivers at Santan and Marangkayu.

| No. | Parameter | Santan | | | Marangkayu | | |
|---|---|---|---|---|---|---|---|
| | | Ci | Lix | PIj | Ci | Lix | Pij |
| 1 | TSS | 20 | 50 | 0,40 | 14 | 50 | 0,28 |
| 2 | DO | 1,09 | 6 | 0,32 | 1,21 | 6 | 0,20 |
| 3 | pH | 3,80 | 6-9 | 0,71 | 3,4 | 6-9 | 0,73 |
| 4 | BOD | 1,02 | 2 | 0,51 | 1,12 | 2 | 0,56 |
| 6 | Iron | 0.55 | 0.3 | 2,31 | 0,44 | 0,3 | 1,84 |
| 7 | Total of coliform | 30 | 1000 | 0,03 | 30 | 1000 | 0,03 |
| | Average | | | 1,70 | | | 1,35 |

*Characteristics of water quality*

The analysis result shows that the chemistry parameter of water quality of watershed in Santan and Marangkayu does not meet quality water standard, referring to government rules number 82 year 2001 about water quality managemen with parameter of TSS, DO, pH, BOD, Fe and the total of coliform. The result of analysis on water quality of rivers in Santan and Marangkayu is provided in the following table 5;

Kadar TSS, BOD, DO pada wilayah penelitian masih tergolong baik. BOD memberikan gambaran banyaknya oksigen yang digunakan oleh aktivitas mikroba selama kurun waktu tertentu. BOD tinggi dalam air tidak diinginkan karena akan mengurangi DO. Kadar BOD menunjukkan kadar limbah organiknya masih tergolong rendah dan air tidak menunjukkan bau menyengat.

Nilai Fe pada sungai santan 0,55 > 0,3 dan sungai Marangkayu 0,44 < 0,3 menunjukkan telah tercemarnya sungai Santan. Pencemaran Fe cukup tinggi diduga tercemar oleh limbah kegiatan tambang batu bara pada wilayah hulu sungai (Fig 2). Luas lahan batu bara yang berada pada DAS Santan yakni 10.427,20 ha (Table 4) dan pada DAS Marangkayu 485,83 ha (Table 5).

The high Fe content influenced pH of water, i.e: 3.8 in Santan watershed and 3.4 in Marangkayu watershed. The pH of water does not meet standard of class II water quality and not eligible for drinking water, fishery and farming. The water is only eligible for irrigating plants. The pH of water is essential element to determine acid or alkaline properties that influence life of water biota. The changes of water pH will significantly affect the life of fish and other animals. According to Djoharam, Riani and Yani (2018), the condition of pH can affect level of toxic in chemical compound, aquatic biochemical process and metabolism process of water organism, when the value of pH is 6-6.5, it will decrease diversity of plankton and micro benthos.

At the researched area, there were found coliform content that shows the river has been contaminated by human feces and animal shits. However, the water condition is still under maximum threshold of 30/1000. The coli bacteria are the indicator of body in water substrate, foodstuffs and so on for the existence of dangerous dead body. The result analysis shows the index of water pollution making up 1.70 > 1.0 in Santan river and 1.35 < 1.0 in Marangkayu river included into light polluted category (Table 5). The research result also shows there is a change of land use; from forest turning into mining, plantation and agriculture purposes. In addition, Huang *et al*, (2013) found negative correlation among forest area, grassland, and water pollution. Moreover, built area causes negative effect toward water quality. Meanwhile, the effect of farming land toward water quality is complex.

## Conclusion

The research result shows the danger level of erosion in Marangkayu is much bigger than in Santan watershed. Land degradation is initiated by mining activities that results critical land and polluted water. Index of land closure in Santan watershed is 69% making it proper as buffer zone. Meanwhile, index of land closure in Marangkayu watershed is 22% making it not suitable for buffer zone.

## Acknowledgment

Our deepest gratitude is expressed to DIRJEN DIKTI (General director of higher education) for giving research funding through graduate scholarship year 2012. Our gratitude is also expressed to University of Widya Gama Mahakam for giving the researcher chances continuing his study on doctoral program.

## References

**Arsyad S.** 2010**.** Konservasi Tanah dan Air. IPB Press, Bogor. 106-154.

**BAPLAN.** 2004. Land Cover Map of the East Kalimantan Province with its Classification and Score. RI Ministry of Forestry, Jakarta.

**Batistella M, Valladares GS.** 2009. Farming Expansionand Land Degradationin Western Bahia, Brazil. Biota Neotrop **9(3),** 61-76.

**Djoharam V, Riani E, Yani M.** 2018. Water Quality Analysis and Pollution Load Capacity of Pesanggrahan River, Province Of DKI Jakarta, Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan **8(1),** 27-133.

**Hardjowigeno S.** 2007. Ilmu Tanah, Akademika Pressindo, Jakarta. 177- 183.

**Huang J, Jinyan Zhan, Haiming Yan, Feng Wu, Xiangzheng Deng.** 2013**.** Evaluation of the Impacts of Land Use on Water Quality: A Case Study in The Chaohu Lake Basin. The Scientific World Journal **(2013),** 1-7.

**Minister of Environment.** 2003. About Guidelines For Determining Water Quality Status, Jakarta **115,** 158-166.

**Nugroho K, Abdurachman A, Amien LI.** 2000. Development and utilization of Agro Ecological Zones in Indonesia using GIS. Di dalam: Kokubun M, Uchida S, Tsurumi K, editor. The 6t" JIRCAS International Symposium: GIS Application for Agro Environmental Issues in Developing Region. Tokyo: JIRCAS.

**Prasena A.** 2013. Assessing The Effects of Land Use Change On Run off In Bedog Sub Watershed Yogyakarta. Indonesian Journal of Geografy **45(1),** 48-61.

**Referring to government rules number 82**

**year.** 2001. About Water Quality Management, Jakarta. 283-296.

**Takamatsu M, Kawasaki A, Rogers, Malakie.** 2014. Development of A Land-Use Forecast Tool for Future Water Resources Assessment: Case Study For The Mekong River 3S Sub-Basins. Journal Sustainability Science **9(2),** 157–172.

**Dong Y, Tingwu Lei, Shuqin Li, Cuiping Yuan, Shumei Zhou, Xiusheng Yang.** 2015. Effects of rye grass coverage on soil loss from loess slopes. Journal International Soil and Water Conservation Research **3(3),** 170-182.