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# The recovery of Tabunio Watershed through enrichment planting using ecologically and economically valuable species in South Kalimantan, Indonesia

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**Abstract**. *Kadir S, Badaruddin, Nurlina, Ridwan I, Rianawaty F. 2016. The recovery of Tabunio Watershed through enrichment planting using ecologically and economically valuable species in South Kalimantan, Indonesia. Biodiversitas 17: 140-147.* Watershed is a medium system where hydrological-biophysical processes as part of hydrological cycle and social, economic, and cultural events as the results of human intervention on natural resource occur. The increasing human population results in the increasing need of water that may reduce the availability of water, causing environmental degradation. The objectives of this study were to study the characteristics of Tabunio watershed and to give recommendation on the enrichment planting for the watershed recovery. This study used watershed ecological area approach and the data were analyzed spatially using GIS. The results showed that based on the characteristics of its components, Tabunio Watershed was categorized as moderately to very highly qualified for recovery. The recovery should be done through: (i) enrichment planting based on the land capability, land suitability and the legal function of the area, (ii) conservation of soil and water using vegetative and civil engineering methods, and (iii) issuance of regulations to increase the watershed's carrying capacity.

**Keywords**: South Kalimantan, Tabunio, watershed recovery, water resource sustainability

## INTRODUCTION

Watershed is a medium system where hydrological-biophysical processes as part of hydrological cycle and social, economic, and cultural events as the results of human intervention on natural resource occur. The increasing human population results in the increasing need of water that may reduce the availability of water, causing environmental degradation. The deteriorating environmental quality has threatened the sustainability of human and other living creatures, so that serious and consistent environmental protection and management must be done by all stakeholders. The program for environmental protection and management for certain period of time should be written in the Planning for Environmental Protection and Management document as part of the Medium Term Development Plan (Act No. 32/2009 regarding the Environmental Protection and Management).

The vulnerability to flood in Tanah Laut District of South Kalimantan Province, Indonesia which is located in Tabunio Watershed increased from 2007 to 2010, with a total of 22 villages being flooded in 2010 (Balitbangda 2010). The area of degraded land in Tabunio Watershed is 19,109.89 ha or 31 % of the watershed area (BPDAS Barito 2013). The recovery of Tabunio Watershed (The Ministry of Forestry Decree No. P.60/MENHUT-II/2014) is expected to create sustainable productive land which functions ecologically optimally to ensure the environmental and hydrological stability and, at the same time, to increase the community's income.

The objective of this study was to know the characteristics of Tabunio Watershed in South Kalimantan Province, Indonesia in order to give recommendation for watershed recovery through enrichment planting of ecologically and economically valuable species. The results of this study can be used as reference for the efforts to meet the water demand in Tabunio Watershed.

## MATERIALS AND METHODS

This study used watershed spatial approach in which the watershed area was divided into three parts: upstream, middle and downstream. The data were analyzed and presented using GIS. The results were recommendation for Tabunio Watershed recovery through enrichment planting. The method of research was based on the Decree of the Ministry of Forestry No. P.60/MENHUT-II/2014 regarding the Determination of Criteria for Watershed Classification. The parameters analyzed were land use, classes of land degradation, water regulation, legal function of the area, and land capability classes for enrichment planting.

The area of Tabunio Watershed is 62,558.56 ha, located in Tanah Laut District, South Kalimantan Province, Indonesia spread in 6 sub-districts. The upstream is 17,542.82 ha, the middle 13,038.44 ha and the downstream 31,977.30 ha. The location of study is given in Figure 1.

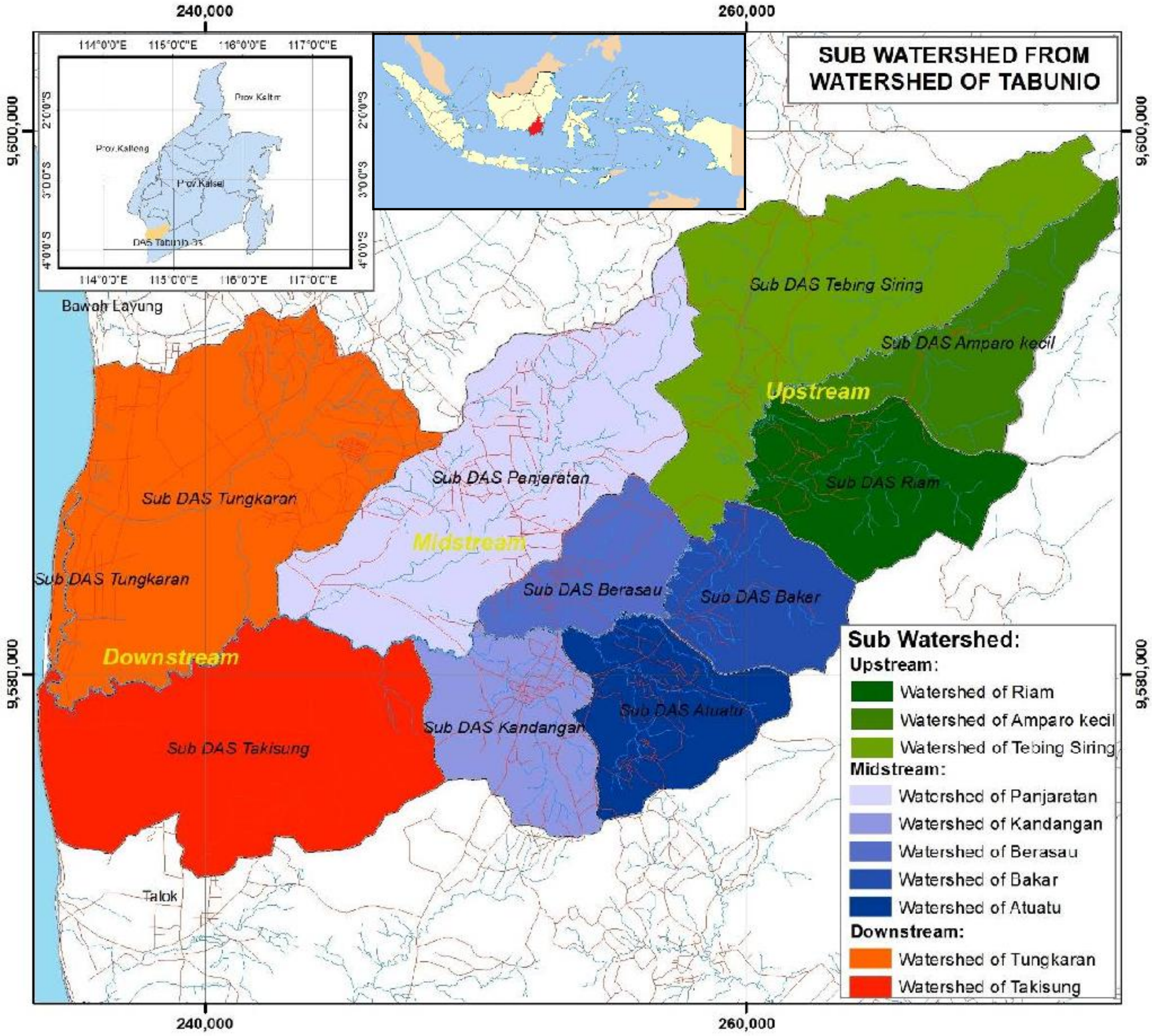


**Figure 1.** The map of Tabunio Watershed and its sub-watersheds in South Kalimantan Province, Indonesia

## RESULTS AND DISCUSSION

The characteristics of Tabunio Watershed which are the main factors to be considered in watershed recovery are land use, land degradation classes, slope, hydrology, the legal function of the area, land capability classes, and plant species for enrichment planting.

### Watershed characteristics

*Land use*

Based on the GIS analyses, there were 15 types of land use in the Tabunio Watershed (Table 1, Figure 2).

Table 1 shows that the permanent vegetation cover in Tabunio Watershed was 24,687.60 ha, or 39.46%, indicating that Tabunio Watershed was categorized as highly qualified for recovery in order to restore its carrying capacity.

Water infiltration is higher and the surface flow is lower in forest than in agriculture land, so vegetation cover should be increased in order to reduce the vulnerability to flood and to increase the community's prosperity (Kometa and Ebot 2012). Meng et al. (2011) stated that the expansion of rubber plantation had reduced the number of forest trees, so the expansion of rubber plantation must be controlled. Zhao et al. (2012) reported that the changes in land use and vegetation cover in watershed affected the surface flow. Liu and Chen (2012) state that the area of agriculture land (non forest) increase with the increasing population.

*Classes of land degradation*

The area of degraded land was determined by overlying land cover, erosion, slope and watershed management. The determination of degradation class was based on the Decree of Director General of Land Rehabilitation and Social Forestry, the Ministry of Forestry no. SK.167/V-SET/2004. The GIS was used for determination of land degradation class, analyses and presentation of spatial data. The area of degraded land is one of determining factors whether a certain watershed needs to be restored or maintained. The results of analyses are presented in Table 2 and Figure 3. Table 2 shows that the area of degraded and critically degraded land was 19,109.89 ha (30.55%). Based on the percentage of degraded land (30.55 %), Tabunio Watershed was categorized as highly qualified for recovery in order to increase its carrying capacity. The distribution of degraded and moderately degraded land is presented in Figure 3.

According to Kadir (2014), the Rehabilitation of Forest and Land is an effort to restore, maintain and improve the function of forest and land, so their carrying capacity, productivity and role as life supporting system can be maintained. Rueda (2010) says that conservation effort can reduce deforestation rate. In addition, Bukhari and Febryano (2008) state that the communities can practice traditional agroforestry system on degraded land based on local condition and wisdom.

*Slope*

Saud (2007) says that water flow increases with the increasing slope. Water, in the steep land, flows faster than in flat land. The results of slope analyses using GIS are presented in Table 3 and Figure 4. Table 3 shows that the slopes of 0-7% dominated the area of Tabunio Watershed (79.85%). Based on its dominant slope, the land is suitable for agriculture crops which can improve the prosperity of community in Tabunio Watershed.

**Table 1.** Types of land use in Tabunio Watershed, South Kalimantan, Indonesia

| Land use types | Area (ha) | | | Total (ha) |
|---|---|---|---|---|
| | Upstream | Middle | Down-stream | |
| Secondary dry forest | 2,343.74 | 201.08 | - | 2,544.82 |
| Secondry mangrove | 5.00 | - | 702.92 | 707.92 |
| Plantation forest | 274.85 | 4,487.91 | 832.07 | 5,594.83 |
| Settlement | - | 416.48 | 36.96 | 453.44 |
| Plantation | 512.69 | 20.65 | - | 533.34 |
| Dry agriculture land | 4,872.93 | 12,986.01 | 9,180.24 | 27,039.18 |
| Dry agriculture land and shrub | 4,347.61 | 1,900.35 | 2,275.88 | 8,523.84 |
| Swamp | - | 11.31 | - | 11.31 |
| Field | - | 984.13 | 5,420.88 | 6,405.01 |
| Shrub/bush | 2,971.28 | 1,320.77 | 3,014.86 | 7,306.91 |
| Shrub/bush on swamp | - | - | 9.30 | 9.30 |
| Fish farming | - | - | 349.52 | 349.52 |
| Mining | 821.47 | 321.02 | - | 1,142.49 |
| Open land | 1,393.30 | 202.99 | 213.53 | 1,809.82 |
| Water body | - | 82.78 | 44.08 | 126.86 |
| Total | 17,542.87 | 22,935.48 | 22,080.24 | 62,558.59 |

**Table 2.** The classes of land degradation in Tabunio Watershed, South Kalimantan, Indonesia

| Classes of degradation | Area (ha) | | | Total (ha) |
|---|---|---|---|---|
| | Upstream | Middle | Down-stream | |
| Not degraded | | | | |
| Potentially degraded | 5,055.94 | 5,213.26 | 3,657.78 | 13,926.98 |
| Moderately degraded | 3,482.32 | 12,771.04 | 13,268.35 | 29,521.71 |
| Degraded | 6,634.49 | 4,861.22 | 5,154.11 | 16,649.82 |
| Critically degraded | 2,370.12 | 89.96 | - | 2,460.08 |
| Total | 17,542.87 | 22,935.48 | 22,080.24 | 62,558.59 |

**Table 3.** Slopes in Tabunio Watershed, South Kalimantan, Indonesia

| Slopes | Area (ha) | | | Total (ha) |
|---|---|---|---|---|
| | Upstream | Middle | Down-steam | |
| 0-2% | 2,566.74 | 9,539.87 | 17,028.13 | 29,134.74 |
| 2-7% | 7,967.23 | 8,959.05 | 3,892.70 | 20,818.98 |
| 7-14% | 2,728.49 | 1,477.09 | 404.77 | 4,610.35 |
| 14-21% | 1,457.51 | 876.84 | 302.30 | 2,636.65 |
| > 21% | 2,822.90 | 2,082.63 | 452.34 | 5,357.87 |
| Total | 17,542.87 | 22,935.48 | 22,080.24 | 62,558.59 |

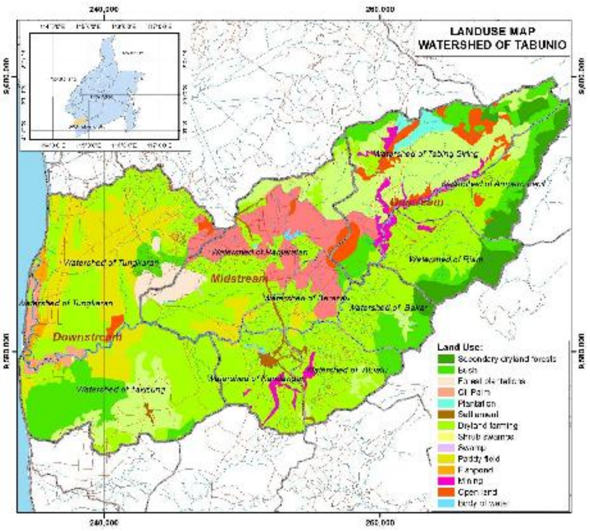


**Figure 2.** The map of land use in Tabunio Watershed, South Kalimantan, Indonesia

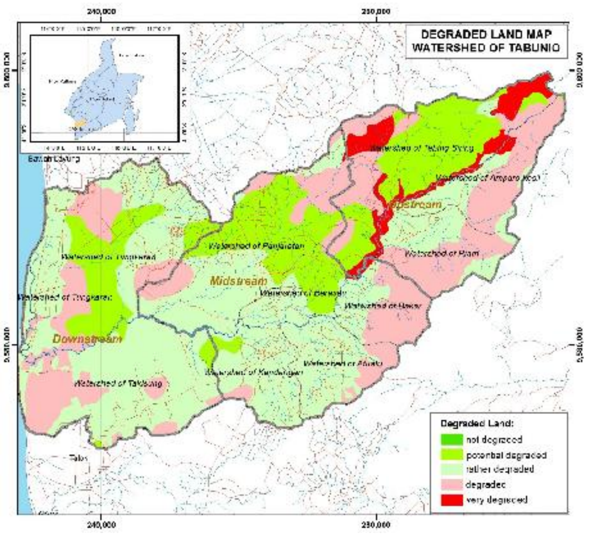


**Figure 3.** The map of degraded land in Tabunio Watershed, South Kalimantan, Indonesia

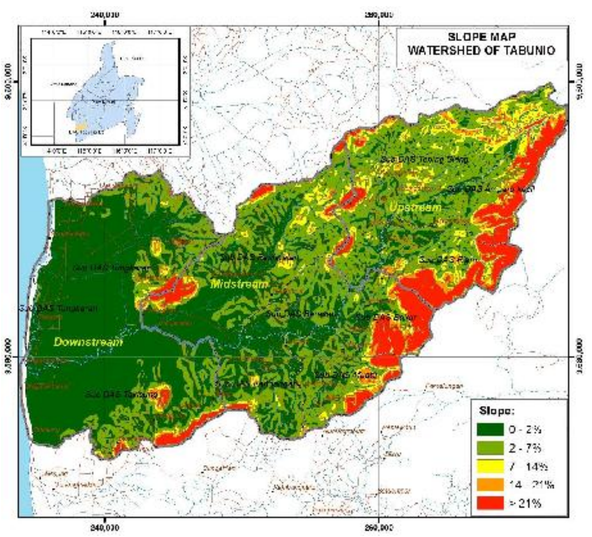


**Figure 4.** The map of slopes in Tabunio Watershed, South Kalimantan, Indonesia

The topography of a watershed affects the speed and volume of surface runoff. Steep slope results in high speed of surface runoff and low infiltration rate (Arsyad 2010). According to Asdak (2010), the upstream of watershed usually has steep slope and dense drainage, so that this part of watershed should be forested.

## Hydrology

*Flow regime coefficient (FRC)*

Flow regime coefficient (FRC) is a number indicating the ratio of maximum water flow (Qmaks) with the dependable water flow (Qa) in a watershed/sub-watershed. The data of water flow from 1978 to 2000 from the Office of Public Work of South Kalimantan Province are presented in Table 4 and Figure 5.

**Table 4.** The average water flow (Q) in Tabunio Watershed, South Kalimantan, Indonesia within a period of 23 years (1978-2000)

| Year | Water flow ($m^3$/second) | | | FRC |
|---|---|---|---|---|
| | Max | Min | Average | |
| 1978 | 3.3 | 2.46 | 18.27 | 0.7 |
| 1979 | 9.5 | 2.89 | 15.58 | 2.4 |
| 1980 | 7.01 | 1.33 | 18.50 | 1.5 |
| 1981 | 45.14 | 2.42 | 14.94 | 12.1 |
| 1982 | 27.49 | 0.39 | 5.22 | 21.1 |
| 1983 | 40.24 | 0.99 | 10.39 | 15.5 |
| 1984 | 2.47 | 0.92 | 9.76 | 1.0 |
| 1985 | 5.7 | 0.99 | 8.64 | 2.6 |
| 1986 | - | - | - | |
| 1987 | 3.3 | 1.17 | 15.83 | 0.8 |
| 1988 | 3.34 | 0.68 | 13.83 | 1.0 |
| 1989 | 8.75 | 0.03 | 10.74 | 3.3 |
| 1990 | 4.99 | 0.89 | 12.50 | 1.6 |
| 1991 | 8.76 | 0.69 | 1.75 | 20.0 |
| 1992 | 36,5 | 0,92 | 11,68 | 12,5 |
| 1993 | 4.4 | 0.99 | 12.81 | 1.4 |
| 1994 | 40.42 | 8.15 | 9.92 | 16.3 |
| 1995 | 3.66 | 1.42 | 10.58 | 1.4 |
| 1996 | 1.49 | 0.6 | 11.65 | 0.5 |
| 1997 | 4.76 | 0.44 | 5.78 | 3.3 |
| 1998 | 9.54 | 1.23 | 13.10 | 2.9 |
| 1999 | 40.24 | 0.42 | 10.14 | 15.9 |
| 2000 | 8.67 | 0.5 | 9.93 | 3.5 |
| Average | 14.5 | 1.4 | 11.4 | 6.4 |

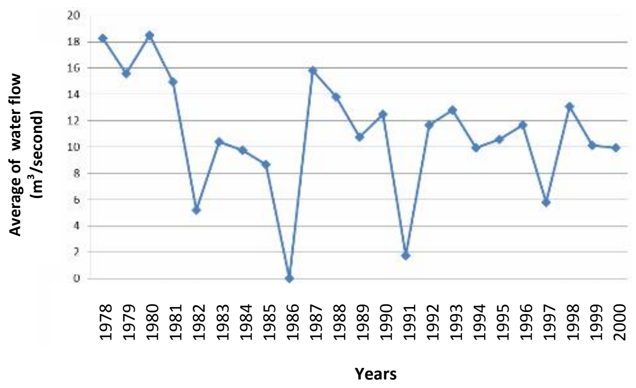


**Figure 5.** The average water flow in Tabunio Watershed, South Kalimantan, Indonesia

Table 4 shows that the maximum water flow within a period of 23 years (1978-2000), was 45.14 $m^3$/second, the dependable water flow was 2.86 $m^3$/second, so the Flow Regime Coeficient (FRC) was > 15.79, meaning that Tabunio Watershed was categorized as highly qualified for recovery. The water flow decreased from 1978 to 2000, and it was even lower in 2015 (from measurement).

Sajikumar and Remya (2015) have analyzed the effect of land use and cover on the characteristics of surface runoff and water flow from two watersheds in Kerala, India. Zhang et al. (2015) have given theoretical basis and technical support for land reclamation and conservation of water and soil in ecologically vulnerable mined land. Furthermore, Fox et al. (2012) analyzed the impact of land cover changes on the runoff and total water flow for a period between 1950 and 2003 in Mediterranean region of France, concluding that the change of land cover affected water flow.

Ma et al. (2010) say that flood control can be done by making water canals and creating artificial peak flood in order to discharge sediment and to increase the volume of water in the rivers. Polonskii and Solodovnikova (2009) recommended flood control by utilizing the water for hydro power.

*Coefficient of flow*

The annual flow coefficient is one of parameters to indicate the hydrological condition of a watershed. The coefficient was calculated from the average annual water flow (11.4 $m^3$/second), rainfall (1583.667 mm/year and area of Tabunio Watershed (62558.56 ha). The coefficient of flow in Tabunio Watershed was 0.36, categorized as moderately qualified for recovery.

*Sediment load*

The sediment load is one of parameters indicating the hydrological condition of a watershed, calculated from the concentration of sediment (0.0008123 gram/liter), average annual water flow (11.4 $m^3$/second) in Tabunio Watershed. The result was 29.20 ton/ha/year, so the Tabunio Watershed was categorized as very highly qualified for recovery.

Inappropriate land use and land ownership cause the loss of biodiversity and the loss of topsoil and its nutrient. Saygın et al. (2011) state that land degradation due to soil erosion is one of the most serious problems. Calvo-Cases and Arnau-Rosalen (2007) reported that potential erosion and surface runoff had increased significantly.

Arribas et al. (2003) reported the result of simulation showing that the impact of land degradation on the climate of the Iberian Peninsula depended on local factors, such as level of degradation and geographical location.

*Flood*

Flood, in this study, is defined as the spill of water from the rivers in Tabunio Watershed, inundating usually-dry areas, causing significant loss materially and immaterially to human and the environment. The data required for this study were flood frequency collected from reports and from direct observation. The data showed that within a year there could be 2-3 times of flooding, indicating that the watershed was categorized as highly qualified for recovery.

Cui et al. (2009) studied the Xiaoqinghe Watershed, China thoroughly to develop a design of river networks in order to reduce flood risk and at the same time to maintain the rivers at their natural condition. The results showed that the design increased connectivity and circuit during the period of low water flow, indicating that the water move faster, reducing the risk of flooding during high water flow.

To improve the success of recovery from flood, all tributaries must be seen as a functional ecosystem, so the recovery can be done integrally as a system. There must be a shift from a tactical approach toward a strategic approach in recovery of rivers and watersheds. Thomas (2014) predicted the possible response of flood frequency with the changes of river network complexity caused by urbanization within a watershed.

**Legal function of the area**

Forest area is a certain area designated by the government to be maintained as permanent forest (Act no 41, 1999 regarding Forestry). The forest area in Tabunio Watershed is categorized into several forest functions (Table 5). Each forest area has different physical conditions, topography, biodiversity and ecosystem types, so each area is designated to a certain forest function. Most area in Tabunio Watershed is non forest area (52,504.80 ha), while the forest area is only 4.031,82 ha.

Table 5 shows that sub-watersheds of Panjaratan and Tebing Siring have the largest protection forest, namely 1,563.89 ha and 682.90 ha respectively. The utilization of protection forest has the objective of improving the prosperity of rural community and at the same time to encourage community to maintain and improve the function of protection forest for the current and next generation through maintaining sustainable water regulation.

The main function of protection forest is to protect life support system through maintaining water regulation, flood protection, erosion control, sea water intrusion prevention, and soil fertility protection. Protection forest is located in the upstream of catchments area and along the river side, according to its function as water regulator as expected in the Act No. 41, 1999 regarding Forestry.

Changes of landuse in protection forest change the hydrological conditions in the river system, which in turn increase the risk of flooding in the urban areas. Therefore, a rational land use must be implemented in order to give maximum benefit and to minimize the negative impact of flood (Zhang and Wang 2007).

**Land capability classes**

The success of traditional gold mined land reclamation is determined by the availability of infrastructure and facilities for reclamation. In addition, the success of conservation of water and soil through vegetative method is determined by land capability class of the land unit.

The results showed that most of the land in Tabunio Watershed had land capability classes of III to VIII, indicating that the land could be used for: (i) limited agriculture, (ii) limited to intensive grazing, (iii) forest, and

(iv) nature reserve. Asdak (2010), Ruslan et al. (2013) and Kadir (2013) state that land use based on land capability may improve the function of watershed ecologically as water regulator and economically by increasing land productivity which in turn increases the community's income. The land capability classes in Tabunio sub-watersheds are presented in Table 6 and Figure 7.

**Recovery of watershed**

Based on the analyses of the characteristics of Tabunio Watershed, the recovery of watershed should be done through the following characteristics:

*Enrichment planting for watershed recovery*

Highland. Rehabilitation of forest and land must be conducted in the upstream area of the watershed, taking into account the land capability classes and land suitability and using economically and ecologically valuable tree species in order to increase the community's income to conserve the ecosystem. The non-forest area could be enriched with rubber trees, and the area of oil palm plantation must be controlled and it must be enriched with deep-rooted trees. The production forest area should be enriched with economically valuable forest tree species. The protection forest area should be maintained according to its function as water regulator through enrichment planting with forest trees (mahogany, teak, etc).

Lowland. Dry lowland and wetland should be enriched with *rengas*, *anglai* and other species which have high ecological and economic value and suitable to the habitat.

*Civil engineering for watershed recovery*

The actions needed include: (i) normalization of river previously used for traditional gold mining in order to increase the carrying capacity, normalization of water flow fluctuation and improvement of water flow speed; (ii) maintenance of river as close as possible to its natural condition both in rural and urban settlement; (iii) construction of infiltration wells, lakes and ponds for sedimentation of mining materials before the water flows into the main rivers; (iv) making of *biopori* in oil palm plantation for water and soil conservation by increasing water infiltration.

*Regulations for watershed recovery*

The activities include: (i) issuing government regulations (or bylaws) regarding the recovery of watershed carrying capacity, so it can function ecologically, socially and economically; (ii) issuing government regulation regarding the planting of deep-rooted along the river side and implementing the regulation in line with related regulations and laws (iii) Limiting the use of land for oil palm plantation only in downstream of Tabunio Watershed.

One of the Tabunio Watershed characteristics was its vegetation cover, which was 39.46%, of the watershed area, indicating that this watershed was categorized as highly qualified for recovery. The percentage of degraded land was 30.55 %, indicating that Tabunio Watershed was categorized as very highly qualified for recovery. The slope of the watershed is mostly 0-7%, indicating that the land is suitable for agriculture activities to increase the prosperity of people living in Tabunio Watershed. The Flow Regime Coefficient was > 15.79, meaning that Tabunio Watershed was categorized as highly qualified for recovery. The coefficient flow was 0.36, indicating the watershed was categorized as moderately qualified for recovery. The sediment load was 29.20 ton/ha/year, meaning that the watershed was categorized as very highly qualified for recovery. According to the people, flooding occurred 2 to 3 times a year, meaning that the watershed was categorized

**Table 6.** Land capability classes in each sub-watershed of Tabunio Watershed, South Kalimantan, Indonesia

| Sub-watershed | Land capability classes | Area (ha) |
|---|---|---|
| Amparo kecil | IV e2 | 3,912.90 |
| Atuatu | IV e2 | 3,676.86 |
| Bakar | III d3o2, IV e2 and VII I5 | 3,161.36 |
| Berasau | III d3o2 and IV e2 | 2,548.65 |
| Kandangan | IV e2 and VIII I6 | 3,651.57 |
| Panjaratan | III d3o2, IV e2 and VII I5 | 9.897,04 |
| Riam | III d3o2, IV e2, VII I5 and VIII I6 | 4,288.91 |
| Takisung | III d3o2 and V o4 | 9,775.09 |
| Tebing Siring | IV e2, VII I5 and VIII I6 | 9,341.06 |
| Tungkaran | III d3o2, IV e2 and V o4 | 12,305.15 |
| Total | | 62,558.59 |

**Table 5.** The legal functions of area in Tabunio Watershed, South Kalimantan, Indonesia

| Sub-watershed | Legal functions of the area | | | | Total (ha) |
|---|---|---|---|---|---|
| | Protection forest | Production forest | Nature reserve | Non forest area | |
| Amparo kecil | | | 3,041.11 | 871.79 | 3,912.90 |
| Atuatu | | | | 3,676.86 | 3,676.86 |
| Bakar | | 251.60 | | 2,909.75 | 3,161.36 |
| Berasau | | | | 2,548.65 | 2,548.65 |
| Kandangan | 70.55 | | | 3,581.02 | 3,651.57 |
| Panjaratan | 1,563.89 | | | 8,333.15 | 9,897.04 |
| Riam | | 1,063.59 | 894.62 | 2,330.70 | 4,288.91 |
| Takisung | 206.86 | | | 9,568.23 | 9,775.09 |
| Tebing Siring | 682.90 | | 2,086.25 | 6,571.91 | 9,341.06 |
| Tungkaran | 192.42 | | | 12.112,73 | 12.305,15 |
| Total | 2,716.62 | 1,315.20 | 6,021.97 | 52,504.80 | 62,558.59 |

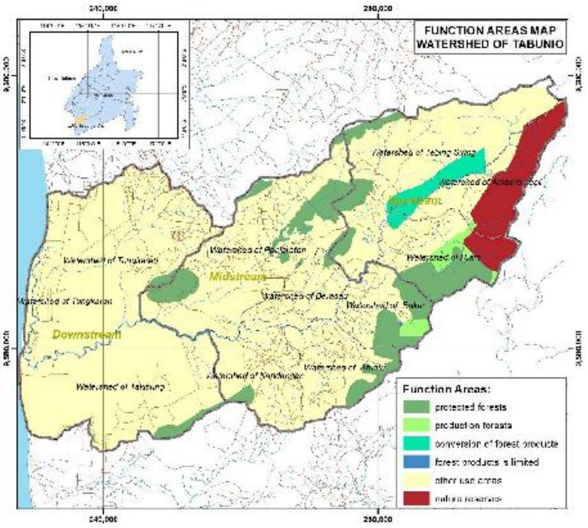


**Figure 6.** The legal functions of the area in Tabunio Watershed, South Kalimantan, Indonesia

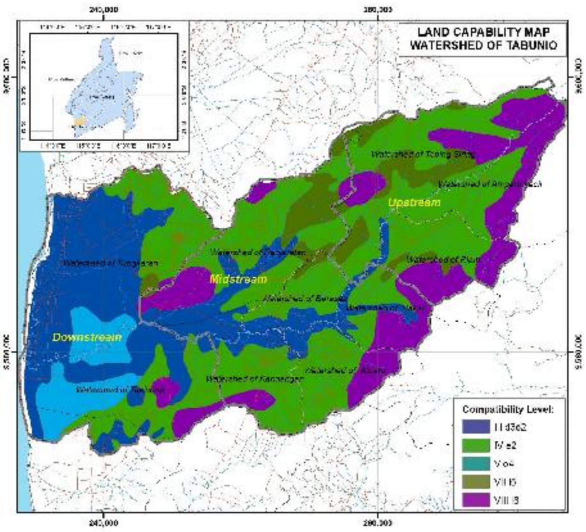


**Figure 7.** The map of land capability classes in Tabunio Watershed, South Kalimantan, Indonesia

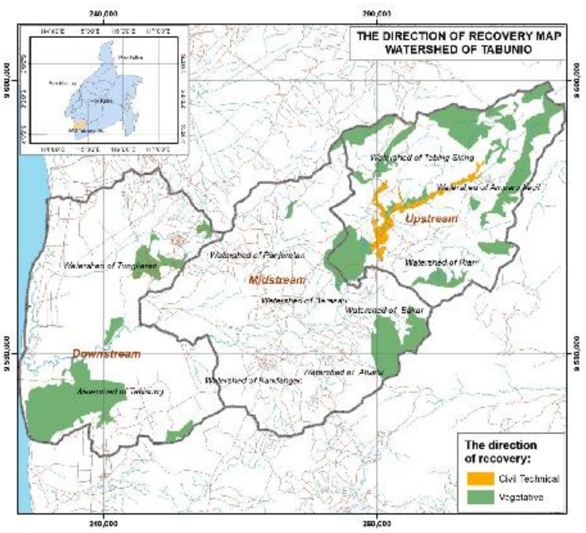


**Figure 8.** The map of recovery plan for Tabunio Watershed, South Kalimantan, Indonesia

as very highly qualified for recovery. Most of Tabunio watershed area is non-forest area, 52,504.80 ha, while the forest area is only 4,031.82 ha. The land capability classes in the watershed were mostly III to VIII. The use of water in the watershed was for vegetation, domestic and industries.

Based on the analyses of the watershed characteristics, recovery must be done through components of the watershed characteristics, using vegetative technique, civil engineering and related regulations. Watershed is an ecosystem which has several components and functions, whether in upstream, middle or downstream, so the watershed recovery must be conducted integrally, involving all stakeholders, all administrative areas for ecological and economic benefits.

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