CHARACTERISTICS OF PHYSICAL CATCHMENT AT LAKE BUYAN AND LAKE TAMBLINGAN, BALI - INDONESIA

Luki Subehi[1], Hendro Wibowo[1], Iwan Ridwansyah[1]
[1]Research Centre for Limnology, Indonesian Institute of Sciences, Cibinong 16911, Indonesia
luki@limnologi.lipi.go.id

ABSTRACT

Lake Buyan-Tamblingan located at an altitude of 1200 m above sea level, is a potential area for tourism industry, residential and agricultural area. An oval-shaped caldera lake with a diameter of 12 x 7 km, named as "endorheic basin" as a confined basin or closed lake basin. The shape of the caldera is natural container basin morphology and therefore, there is no direct inflow or outflow. The objective of this study is to analysis of physical characteristics catchment at Lake Buyan and Lake Tamblingan. The survey was conducted on October 2013. Rainwater that falls will be collected in a container of water and percolate as groundwater in the basin. There is also a flow of groundwater that flows very slowly out as the springs basin in the lower region. The morphometric showed extensive Lake Buyan 3.67 km^2 with a maximum depth of 79.5 m. Those lakes have an area of 1.15 km2 where lake Tamblingan with a maximum depth of 40 m. The average depth of Lake Buyan and Tamblingan is 31.7 m and 23.5 m, respectively. The result of land use changes showed the largest land changes occur in forest cover reached 123.5 ha. Most of the forest cover turned into plantations and agricultural areas. The growth of urban residential in this catchmentfrom 76.4 ha to 118.2 ha, mostly from rice fields and agricultural areas. Sedimentation in lakes Buyan and Tamblingan using hydrological models SWAT, sediment load simulation results lakes Buyan and Tamblingan is 134.2 ton/year and 111 ton/year. If allowed to continue these activities then would threaten the sustainability of the lake.

Keywords: Lake Buyan – Lake Tamblingan – Morphometric – Caldera lake – Land use

INTRODUCTION

Lake Buyan-Tamblingan are lies at 1200 m above sea level in the middle of Bali island where have a destination for tourism potential, seattlement, agriculture and fertile land. This region is located at the foot of Tapak hill, Lesung dna Pohen where it is a protected area. This area is part of the landscape shaped hollows special because they have no relationship with water flowing into the sea directly.

The landscape of thistype basin was named as "endorheic basin" or a confined basin (closed lake basin). This type is formed by a series of geological events that took place a few hundred to thousands of years. The massive eruptionhas destroyed most of the ancient volcanic peaks and slopes, leaving only now forming elliptical caldera with a diameter 12 x 7 km.

The shape of the caldera affects a hollow morphology, no direct flow of water out (to sea). Rainwater that falls will be accommodated in a basin lake and percolate as groundwater in the basin (Ward and Robinson 2000). The water coming out of the basin was only evaporation from water bodies and evapotranspiration from plants.

Groundwater also flows very slowly out into the spring basin in the lower region. The objective of this study is to analysis of physical characteristics catchment at Lake Buyan and Lake Tamblingan

METHODS

From previous data (Kayane et al 1993; Tanaka 2008) and the results of the survey of Botanical Garden "Eka Karya" Bali team in 2005 showed Lake Buyan has area of 3.67 km^2 with a maximum depth of 79.5 m. Meanwhile, Lake Tamblingan has area of 1.15 km^2 with a maximum depth of 40 m. The averages depth for Lake Buyan and Tamblingan are 31.7 m and 23.5 m, respectively. Water levels in both lakes are 1,214 m above sea level (Fig. 1).

The activities (plantation, settlement, tourism, etc.) influenced morphometry and bathymetry changes at both lakes due to sedimentation and silting.Studies on sedimentation parameters (grain size, rate of deposition, erosion processes), the level of lake eutrophication (water quality parameters, nutrient abundance) and the abundance of aquatic vegetation condition/macrophyte that can disrupt the aquatic environment of the lake are should be investigated in the future. In addition, forest area around Lake Buyan-Tamblingan also is one of the tropical rain forest in Bali. This forest plays an important role in maintaining the stability of ecosystems, preventing erosion and disasters as well as a source of water in the surrounding area.But now the mountain forests endangered because of human activity.

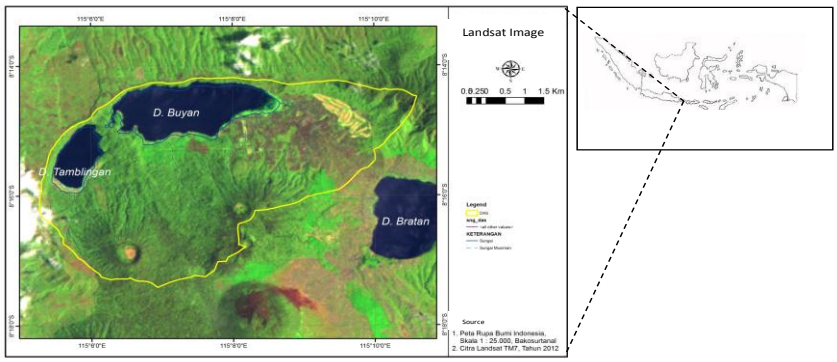

Fig. 1 Site Location

We analyzed land use at Buyan-Tamblingan catchmentfrom Landsat satellite image classification results in 2012. In addition, we also obtained land use classified

from Indonesian RBI (Rupa Bumi Indonesia) maps, scale 1: 25,000, published by Bakosurtanal (BIG). We compared the land use condition between 1994 and 2012.

Supporting SWAT model, we analyze the total loading sediment for both lakes. Moreover, we conducted the sampling analysis at three stations (two stations at Lake Buyan and one station at Lake Tamblingan). We measured the TSS and sediment rates.

RESULTS

Morphometryof catchment

Slope

Slope is an important parameter in the management of a catchment, as one factor to determine the arrangement of the area. Lake Buyan - Tamblingan catchment tends to be steep sloped mountains. The slope is dominated by grade of 15% - 30% with an area of 1094 ha or 38% of the total basin area where occupied by forest cover, plantations and agriculture (Fig. 2). Meanwhile, the flat areas are found in the western part of the catchment(462.5 ha) or 16% of the catchment area where are used for settlement and agriculture. A very steep slope (> 45%) found on the peak of mountain and the northern of Lake Buyan – Tamblingan (345 ha) or 12% of the catchment area and all covered by forest.

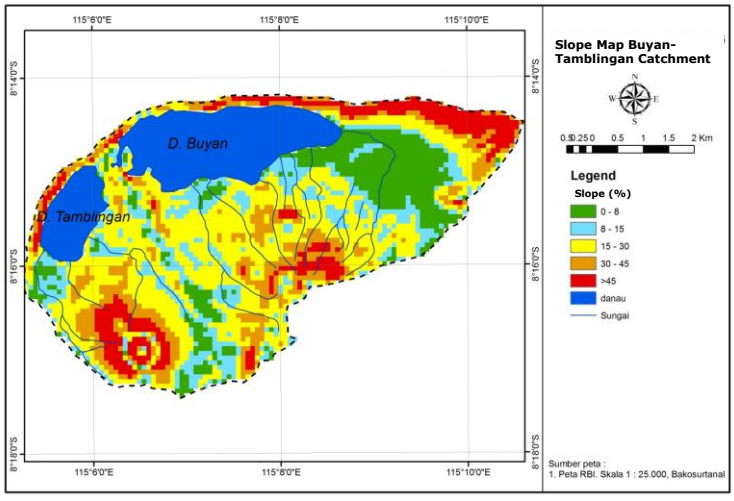

Fig. 2 Map of slope at Buyan – Tamblingan catchment

Land use

Land use at Buyan-Tamblingan catchment was obtained from Landsat satellite image classification results in 2012. Land use classes used by Indonesian RBI (Rupa Bumi Indonesia) maps, scale 1: 25,000, published by Bakosurtanal (BIG). RBI map is also used as a comparison in the analysis of land use changes in the catchment. Based on RBI map, land use at Buyan-Tamblingan catchmentin 1994 was dominated by forest cover with an area of 2,335.8 ha or reaches 63% of the total area of the catchment and lake. The area of lakes reached 626 ha (17%). Figure 3 shows the land use at Buyan-Tamblingan catchment on October 2012, such as plantation, agriculture, sport area (golf), part of clear cutting forest , etc.

Fig. 3 Land use at Buyan-Tamblingan catchment

Increasing of natural resources needed as a result of population growth and economic development, conflicts of interest and lack of integration among stakeholders/sectors influenced the degradation of environment. Mismanagement between regions upstream and downstream cause damage to the catchment (Turner et al 1994; Turner 1997). The damage generally occurs due to land conversion Buyan-Tamblingan catchment. Generally, the change of land will change: (a) the

characteristics of the river flow, (b) the amount of surface runoff, (c) the nature of the relevant hydrological regions (Tani 1997).

The results of changes in land use are shown in Table 1 where the largest land changes occur in forest cover, which reaches 123.5 ha. On the other hand, the growth of urban residential in this catchmentfrom 76.4 ha to 118.2 ha, mostly from rice fields and agricultural areas.

Table. 1 Area of the land use change at Buyan-Tamblingan catchment

Land Use	1994		2012		Land UseChange
	Area (Ha)	%	Area (Ha)	%	Area (Ha)
Inland water	626.6	16.899	626.6	16.899	0.0
Shrubs	23.8	0.642	49.9	1.345	26.1
Building	0.1	0.003	0.2	0.006	0.1
Forest	2355.8	63.531	2232.3	60.201	-123.5
Plantations	90.3	2.435	84.2	2.271	-6.1
Settlements	76.4	2.059	118.2	3.187	41.8
Grass	21.1	0.568	54.0	1.456	32.9
Irrigation rice field	219.8	5.928	213.8	5.765	-6.0
Rainfed rice field	222.4	5.998	226.6	6.112	4.2
Field	71.8	1.937	102.3	2.759	30.5
Total	3708.1	100.0	3708.1	100.0	

Catchment areas can be viewed as a hydrological unit, which means that the watershed can serve to modify input in the form of rain into outputs such as water and sediment. Outcome of a catchmentis strongly influenced by inputs and processes that occur in the catchment (interception, infiltration, percolation, and surface water flow). The processes at catchment are related to the characteristics of soil properties, topography, land use, soil surface conditions (surface storage and surface detention), geomorphology and watershed morphometry.

Based on SWAT analysis in Table 2, the changes of total sediment loading at Lake Buyan and Lake Tamblingan between 1994 and 2012 were shown. The change of sediment loading from 1994 to 2012 at Lake Buyan (1.2 ton/year) was smaller than that at Lake Tamblingan (5 ton/year). But in fact, sediment loading for 2012 at Lake Buyan (134.2 ton/year) was larger than that at Lake Tamblingan (111 ton/year). It seemed that the land use at Lake Buyan was more changes from human activities.

Tabel 2. Simulation result from SWAT model

2012	1994
Lake Buyan	
PRECIP = 5222.1 MM *SURFACE RUNOFF Q = 1051.55 MM* *LATERAL SOIL Q = 787.68 MM* *GROUNDWATER (SHAL AQ) Q = 2359.09 MM* *DEEP AQ RECHARGE = 127.47 MM* *TOTAL AQ RECHARGE = 2549.47 MM* *TOTAL WATER YLD = 4197.18 MM* *PERCOLATION OUT OF SOIL = 2653.32 MM* *ET = 718.5 MM* *PET = 1072.7MM* *TOTAL SEDIMENT LOADING = 134.2 tons/year*	PRECIP = 5222.1 MM SURFACE RUNOFF Q = 986.85 MM LATERAL SOIL Q = 792.62 MM GROUNDWATER (SHAL AQ) Q = 2412.28 MM DEEP AQ RECHARGE = 130.31 MM TOTAL AQ RECHARGE = 2606.19 MM TOTAL WATER YLD = 4190.71 MM PERCOLATION OUT OF SOIL = 2712.05 MM ET = 719.4 MM PET = 1072.7MM TOTAL SEDIMENT LOADING = 133 tons/year
Lake Tamblingan	
PRECIP = 5101.8 MM *SURFACE RUNOFF Q = 843.34 MM* *LATERAL SOIL Q = 820.72 MM* *GROUNDWATER (SHAL AQ) Q = 2431.90 MM* *DEEP AQ RECHARGE = 131.21 MM* *TOTAL AQ RECHARGE = 2624.26 MM* *TOTAL WATER YLD = 4095.06 MM* *PERCOLATION OUT OF SOIL = 2726.80 MM* *ET = 688.3 MM* *PET = 1073.0MM* *TOTAL SEDIMENT LOADING = 111 tons/year*	*PRECIP = 5101.8 MM* *SURFACE RUNOFF Q = 799.33 MM* *LATERAL SOIL Q = 828.47 MM* *GROUNDWATER (SHAL AQ) Q = 2463.63 MM* *DEEP AQ RECHARGE = 132.90 MM* *TOTAL AQ RECHARGE = 2658.05 MM* *TOTAL WATER YLD = 4090.64 MM* *PERCOLATION OUT OF SOIL = 2761.82 MM* *ET = 689.3 MM* *PET = 1073.0MM* *TOTAL SEDIMENT LOADING = 106 tons/year*

Moreover, from SWAT model, it showed that daily loading sediment at Lake buyan was larger than that at Lake Tamblingan for 2012 (Fig. 4 & 5). Based on those figures, the changes of land use at Lake Buyan catchmentcan not be avoided due to population growth and the rate of the economy, the impact of land use changes will directly affect the ecosystem of the lake due to fluctuations in discharge and sediment loading.

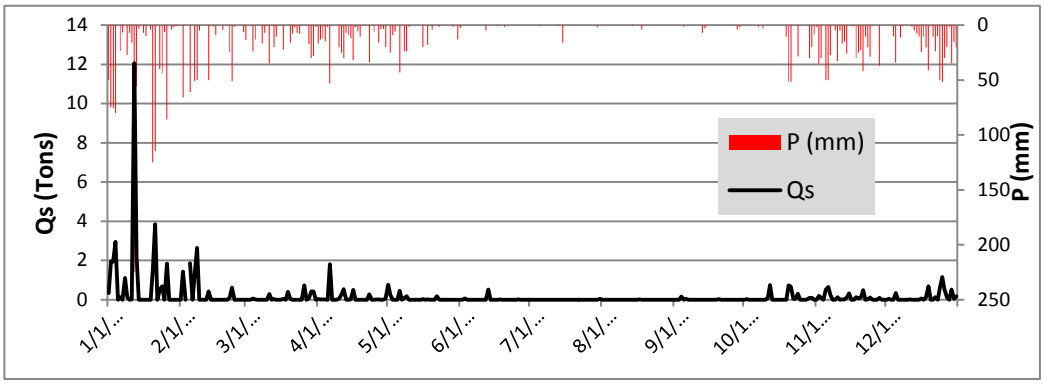

Fig. 4. Daily loading sediment at Lake Buyan 2012

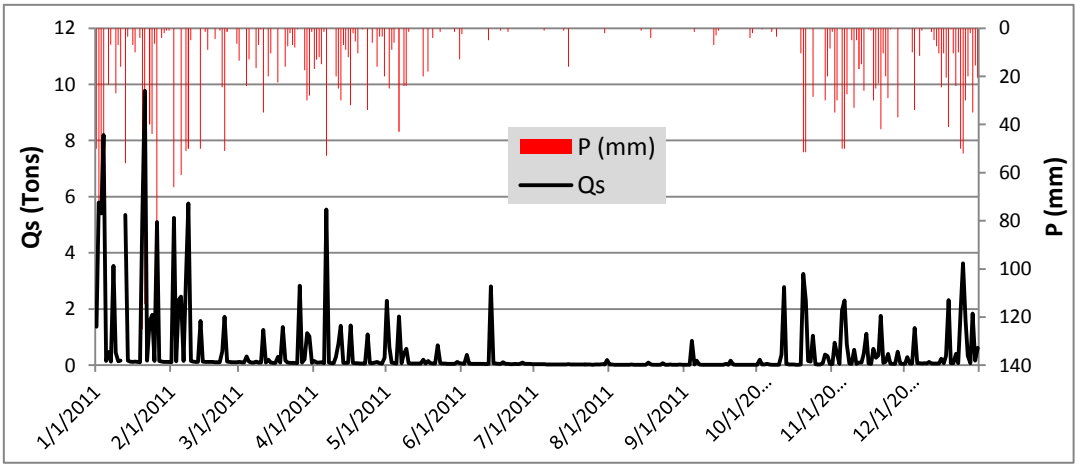

Fig. 5. Daily loading sediment at Lake Tamblingan 2012

Compared with the area of catchment of lake, sediment levels in both sites classified still good condition. In general, it still dominance covered by forests. Forest canopy can protect the soil from demolition by the kinetic energy of rain as the erosion of material transported by surface runoff.

Next, sedimentation rates in the lake can be approached with the installation of a sediment trap tubes mounted on the 0.6 part of the depth of the lake (Fig. 6). The total weight of the sediment is trapped in the tube for long installation time is the value of the velocity sedimentation. Measurements were made at two points at Lake Buyan and one point at Lake Tamblingan (Fig. 7). In addition, no inflow coming from the catchment showed total particulate deposition changes as shown in Table 3.

Fig.6 Survey activities at Lake Buyan and Lake Tamblingan

Tabel.3 Sedimentation rates

Sample	Total changes in particulate deposition ($mg/cm^2/day$)
Buyan 1	0,122
Buyan 2	0,152
Tamblingan	0,128

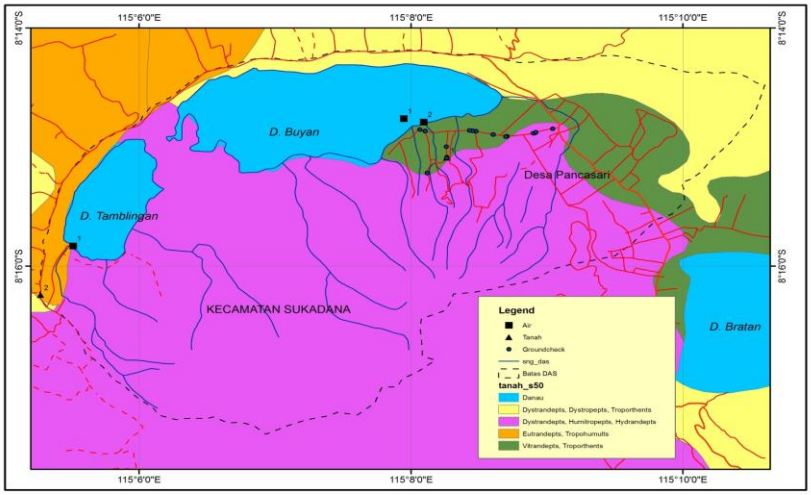

Fig. 7 Sampling locations at both lakes

These results (Table. 3) indicated that the total change in particulate deposition were low in the lakes at the time there was no inflow from the catchment. Installation of traps with a distribution that is representative represents the overall condition of the lake can be used to calculate the speed of sedimentation in the lake.

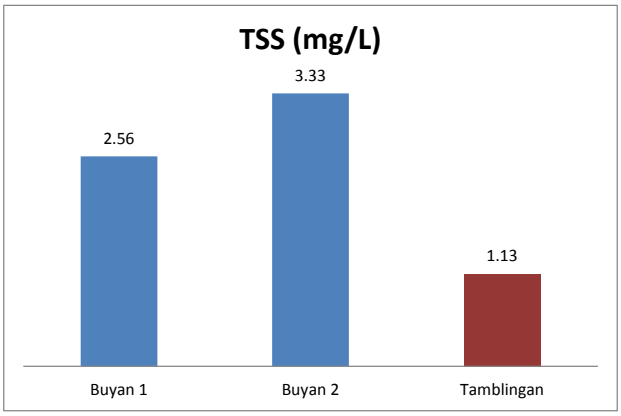

Fig. 8 TSS values for each sampling station at both lakes

From analysis of TSS for each sampling station (Fig. 8), it showed that the TSS value at Lake Buyan (2.56 mg/L and 3.33 mg/L) was larger than that at Lake Tamblingan (1.13 mg/L). It seemed that Lake Buyan obtained more input flow from catchment area as resulted from the changes in land use.

CONCLUSION

From SWAT model, total sediment loading at Lake Buyan was larger than that at Lake Tamblingan (134.2 ton/year and 111 ton/year, respectively). Meanwhile, TSS value for each sampling station at Lake Buyan (2.56 mg/L and 3.33 mg/L) was also larger than that at Lake Tamblingan (1.13 mg/L). Lake Buyan tended obtaining more impacts from the larger changes in land use. It seemed that the human activites (agriculture, plantation, settlement, tourism, etc.) could influence the lake catchment conditions.

Further studies on sediment and nutrient loads from catchment, measuring bathymetry, water quality, and lake sedimentation velocity should be done in order to further characteristics information as a basis for management sustainability at both lakes**.**

REFERENCES

Kayane I, Tanaka T, Shimada J, Sakura Y, Itadera K, Shimano Y, Shimmi O, Mori K, Nakai N (1993) Investigation of the water cycle using environmental tracers, Bali, Indonesia. Hydrology of Warm Humid Regions, Proceedings of The Yokohama Symposium , IAHS Publ. No 216 : 305 – 316.

RBI (Rupa Bumi Indonesia) maps, scale 1: 25,000, published by Badan Informasi Geospasial (BIG).

Tanaka T (2008) Methodology of integrated watershed management for sustainable water resources use. Bull. TERC, Univ. Tsukuba No. 8 Supplement, No. 2 : 13 – 17.

Tani M (1997) Runoff generation processes estimated from hydrological observations on a steep forested hillslope with a thin soil layer. Journal of Hydrology, 200: 84–109.

Turner II BL (1997) The sustainability principle in global agendas implications for understanding land-use/land-cover change. The Geographical Journal, Vol. 163 No. 2 : 133 – 140.

Turner II BL, Meyer WB, Skole DL (1994) Global land-use/land-cover change: towards an integrated study. Ambio Vol. 23 No. 1 : 91 - 95.

Ward RC, Robinson M (2000) Principles of hydrology, McGraw-Hill, UK, 450 pp.