Advances in Social Science, Education and Humanities Research, volume 613
4th International Conference on Innovative Research Across Disciplines (ICIRAD 2021)

Simulation-Prediction Model of Soil Erosion in Lake Buyan

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ABSTRACT
The existence of the lake is very important for the Balinese people, as a source of drinking water, as well as in the spiritual aspects of Hindu religion. One of the lakes on the island of Bali is Lake Buyan. Geographically, it is located in Pancasari village, Sukasada district, Buleleng, Bali. The Bali Provincial Public Works Department ' Data shows that in the last 15 years from 1999 to 2015, there is an increasing decrease in the area of the lake. In 1999 the area of the lake was recorded at 439 Ha and shrunk in 2015 to 376 Ha. One of the factors that affect the area of the lake is the occurrence of soil erosion. In this study, a simulation model was developed to predict landslide/soil erosion conditions in Lake Buyan. This avalanche simulation model is based on the USLE (Universal Soil Loss Equation) formula. It is stated that erosion is influenced by soil erobility, rain erosivity, steepness of slopes, tillage, and soil conversion. Based on the developed simulation model, it is shown that the biggest influence that affects the landslide in Buyan Lake is rain erosivity. Rainfall predictions based on rainfall data for the last 10 years show that the rainfall is getting smaller. On the one hand, it will bring the advantage that the quantity of landslide erosion in the next few decades will be smaller. Based on the simulation model, predictions show that in 2020, 2030, 2040, and 2050 the amount of erosion is 116.5 tons, 74.23 tons, 18.62 tons, and 7.5 tons. On the other hand, this is very worrying because rain is the only source of water for Lake Buyan.

Keywords: *Lake Erotion, USLE, Dynamic Simulation, Buyan Lake.*

1. INTRODUCTION

The lake is one of the most important environmental aspects, which is a life support for the surrounding community. Bali has 4 large lakes, Lake Batur in Bangli Regency (1607, 5 Ha), Lake Bratan in Tabanan Regency (370 Ha), and Lake Buyan (360 Ha) and Tamblingan (110) in Buleleng Regency [1]. The four lakes are called *'Catur danu'*, which are the source of life for the Balinese people, the four lakes in their main function as producers of clean water sources for the Balinese people.

Respect for the lake in sad kertih is called danu kertih, which is an effort to maintain fresh water sources on land, such as springs, lakes, rivers, and others. The lake is a place where religious ceremonies are carried out in the form of rituals and are sacred. Like the mapekelem ceremony / salvation ceremony to the lake, and there are also people who carry out the melasti ceremony to the lake [2], [3].

Buyan lake, which is in the administrative village of Pancasari, Sukasada district, Buleleng district. Together with Tamblingan Lake, it is a source of drinking water for Buleleng Regency, and the city of Singaraja in general. Some people say the two lakes are twin lakes. Based on research conducted by the Udayana university team, [4], [5] For Lake Buyan in 1999, the area of the lake was about 439 Ha, ten years later it shrank by 5.9%, the area was only 413.15 Ha, then in 2015, only 376.6 Ha. from the period 2009 to 2015, the period of 6 years depreciation was 8.8%.

There are many factors that cause lakes to decline in quality, both in terms of area, volume and water quality. In the data from the Public Works Agency [6], it is stated that several main problems of Lake Buyan include (1)

unclear land boundaries of the lake so that it causes a lot of land use change, (2) high waste of agricultural and fishery activities, (3) very high sedimentation, (4) non-ideal land elevation, (4) Illegal extraction of water.

Many factors that cause lakes to decline in quality, both in terms of area, volume and water quality. In the PU Department data [6], it is stated that several main problems of Lake Buyan include (1) unclear land boundaries of the lake so that it causes a lot of land use change, (2) high waste of agricultural and fishery activities, (3) very high sedimentation, (4) land elevation that is not ideal, (4) illegal extraction of water.

One of the dominant problems affecting the area and volume of the lake is the occurrence of landslides/erosion. The quality of landslides and soil erosion is influenced by natural conditions and excessive human activities [4], [7], [8], [9]. In this study, a simulation model is analyzed to predict landslide conditions in Buyan Lake in the future time.

2. LITERATURE OF STUDY

2.1 The Environmental Conditions of Lake Buyan

Buyan lake is one of the lakes mentioned as Tri danu in the article [2]. Geographically, Buyan Lake, Panca Sari Village, Sukasada District, Buleleng Regency. This lake is a source of drinking water and agriculture for the people of Central Bali, especially Buleleng Regency. Besides being a source of drinking water, Buyan Lake also provides benefits for fertile agricultural land (in the lakeside area), an extraordinary tourist charm. Realizing this, the Buleleng district government has actually made efforts to protect it, such as government regulation No. 36 of 2005, which regulates environmental and building layouts around Buyan Lake. Figure 1 shows the geographic location of Buyan Lake [10].

Buyan Lake is a caldera lake, which is a confined basin. The source of input water for Buyan Lake is rainwater. There are no rivers that enter as a source of water supply. Based on interviews with local communities, seepage occurred between three adjoining lakes, Lake Bratan, Buyan, Tambilangan.

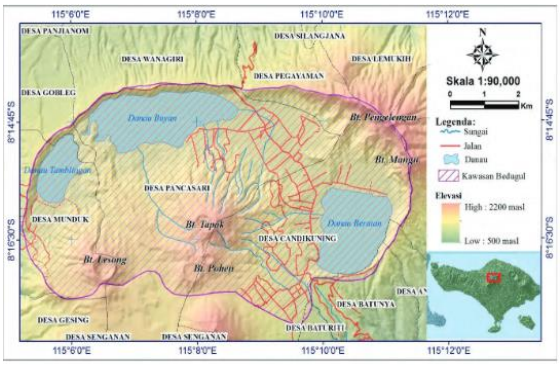

Figure 1. Map of Buyan Lake Bedugul Bali.

Some environmental conditions of Lake Buyan are shown in table 1 and Furthermore, the rainfall factor, the data is shown in table 2 by data +/- the last 10 years 2010-2019, taken from the Baturiti/Pancasari weather post.

2.2 Analysis of Erotion Land

One approach used to measure erosion quality is to use the USLE formula (Universal Soil Loss Equation).

$$A = R.K.Ls.C.P \quad .(1)$$

A : Erotion of Soil (ton/Ha/tahun)

R : Erosivitas of Rain

K: Erobilitas of Soil

Ls : Land slope

C: Cultivation of Land

P: Conservation of Land

Table 1 . The Condition of Buyan Lake Environment Parameter

Parameter	Value	Description
Land slope	3.1	Land Slope 15-25%
Conversion of Land	0.5	planting following the contours of the land
Land cultivation	0.4	Potato farmland, vegetables
Erobilitas of Land	0.21	Meditern

Table 2. The Rainfall in Baturiti-Pancasari Bedugul

Tahun	Januari	Februari	Maret	April	Mei	Juni	Juli	Agustus	September	Oktober	November	Desember
2010	645.4	458.4	373.9	701.4	302	119.5	108.4	130.7	279.9	509.4	368	573.6
2011	558.2	405.7	165.5	445.7	285.1	13	22.9	6.2	49.7	121.6	342.1	338.3
2012	565.3	332.7	444.1	362.9	156.3	17.3	90.6	10.9	6.1	136.4	273	401.7
2013	294.5	550	333.7	328	220.8	207.8	141	20	13	18	344	491
2014	388	134	94	198	60	4	141	22		25	478	554
2015	326	233	534	298	89	20	9	14	22		127	351
2016	315	640	312	260	410	130	284	153	248	337	484	506
2017	513	396	402	305	147	106	106	51	47	270	469	447.9
2018	644.9	616.1	446.6	163.6	43.7	104.9	93.4	177.8	29.6	20.5	425.4	297.6
2019	563.7	261	469.9	446	70.1	128.2	11.9	8.4	9.4	1.4	275.9	310

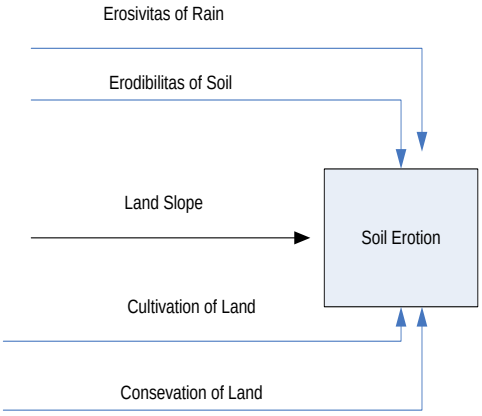

Figure 2. Causal Diagram of Model Erosion in Lake Buyan

2.2.1. Erosivitas of Rain (R)

Rain erosivity is determined by the equation proposed stated :

$$R = 10.8 + 4.15 .CH$$

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(2)

R erosivity of rain , influenced by monthly rainfall (CH) , expressed in units (KJ/Ha)

2.2.2 Erodibilitas of Soil (K)

Soil erodibility is an index of soil sensitivity to natural factors, which cause erosion. Quantitatively, soil erodibility (K) states the amount of soil lost on average per year per unit area.

2.2.3 Slope of Land (Ls)

LS is a combination of graded L (length of span) of the slope, and S (slope) of the slope. LS is one of the variables that determine the quality of erosion based on the USLE formula, which is stated in Equation 1. LS physically states the ratio of soil loss in a certain unit area, to the length (L) of the slope and the slope in that area.

2.2.4. The Cultivation of Land (C)

Soil tillage factors are associated with the types of plants that grow and are cultivated on the land, processing of crop residues, processing time, and soil fertility conditions. Several approaches are used to determine the tillage value (C).

2.2.5. The Conversation of Land (P)

Practical land conversion is the amount of land that is lost if conservation is carried out on land, for example making terraces, plants in contours, and others.

2.3 The Modeling of Dynamic Simulation

One of the existing simulation model methods is the dynamic simulation model, which is a simulation model that involves time as an influential factor. In dynamic modeling, the goal is to describe quantitative changes in one or more certain variables. To be able to do this, the details of the system must be determined, the characteristics, the phenomena that occur in it, the elements that make up the system, the relationships and interrelationships between the constituent elements (system structure). All of them refer to the field of science related to the discussion of systems. For lake systems, there will be a lot of involvement in civil engineering, especially soil science for landslide analysis, biological or environmental sciences for discussing lake biomass, chemistry for analysis of lake inorganic organic matter content, fisheries science for lake fisheries activities. From the analysis of various disciplines, the structure of

the system is finally obtained, which is then used as the basis for determining the causal model / structural model and finally being used as a behavior model (final simulation model).

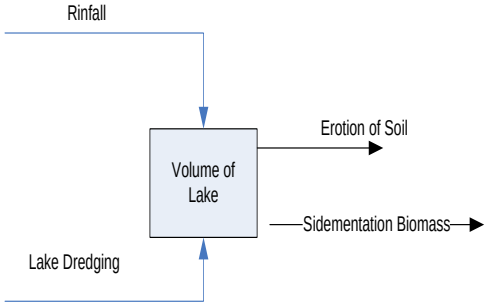

Figure.3. Causal Diagram Exsistention of Lake

The Buyan lake model based on a review of soil science and the occurrence of sedimentation, we state in this study expressed by the variable area (Ha) / water volume (million m3) of the lake, influenced by 3 factors. Rainfall as the main water source for the catchment area (catchment area) of Lake Buyan. There is also no river flowing from Buyan Lake, Buyan Lake is truly a perfectly confined basin. The possibility of seepage from rocks exists. The second factor that affects the area and volume of the lake is the landslide/soil erosion around the lake. The third factor is sidementation due to biomass decomposition.

3. METHOD

3.1 Data Acquisition

The data used are data issued by the official agency of the Public Works Agency (PU) of the province of Bali, Meteorological Agency data, as well as data from previous research results. The following is the data obtained related to the condition of Lake Buyan. These data are shown in Table 1 and Table 2. Furthermore, these data are used to develop a simulation model based on the USLE formula, Equation 1.

Some assumptions that are also taken in this research are:

1. Soil steepness/slope, expressed as a constant, whose value is fixed and is formed by natural influences. In this study, referring to the data of Lake Buyan, the steepness constant is 3.1. This value shows 15-20%, relatively steep conditions.
2. Soil erosion, real conditions currently show a value of 0.21 Mediterranean conditions, this value will change, if human activities are too excessive, but the process will take a very long time. In the simulation, a simulation model of the change value of 1% is made every year. So far, the author has not found the rate of change in soil erosion and what factors influence it.
3. Rain erosivity, expressed as a function affected by rainfall. The rainfall pattern used to predict rain for the next few decades is to use a rainfall pattern from 2010 to 2019. The pattern shows less rain from year to year in the future.
4. Tillage, in the initial condition study, was given a value of 0.4, indicating a lot of potato fields, and other vegetables around the lake. This value will increase with population growth. In this condition, it is assumed that there is an additional 1% of land around the lake every year. This 1% value needs to be studied further.
5. Soil conversion factor, land conversion factor, currently in Buyan Lake, farmers are planting slopes according to hilly land contours, this condition is predicted / assumed to be getting worse, the change rate used for land conversion is 1%. The conversion value of the land around Buyan Lake is 0.5, there is no massive conservation yet.

3.2 Model Simulation

The simulation was developed using Powersim software. The data simulation is based on the data and assumptions stated above. For rainfall , the graph function is used. It is used to predict rainfall based on 2010-2019 rain data. Figure 4 shows a structural diagram of the landslide/erosion simulation model of Lake Buyan.

4. RESULT AND DISCUSSION

4.1 Result

The simulation results of landslide data for 2020 - 2050 are shown in Table 3, and the graphical simulation is in Figure 5.

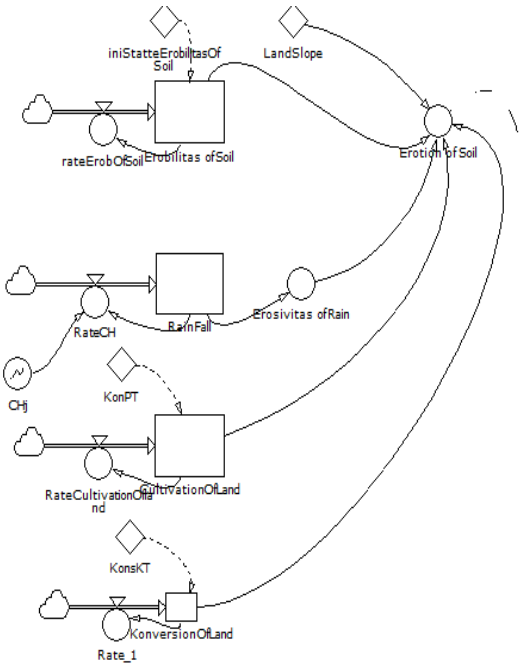

Figure 4. Model Simulation of Erotion Buyan Lake

Table 3. Result Of Simulation Erotion Buyan Lake 2020- 2050

year	Kecuraman	Erobilitas Tanah	Erosivitas Hujan	Pengolahan Tanah	Konversi Tanah	Erosi Lonsoran
2,020	3.10	0.21	894.75	0.40	0.50	116.50
2,021	3.10	0.21	544.71	0.40	0.51	73.07
2,022	3.10	0.21	551.65	0.41	0.51	76.24
2,023	3.10	0.22	584.10	0.41	0.52	83.17
2,024	3.10	0.22	453.96	0.42	0.52	66.60
2,025	3.10	0.22	437.56	0.42	0.53	66.14
2,026	3.10	0.22	799.46	0.42	0.53	124.51
2,027	3.10	0.23	641.72	0.43	0.54	102.97
2,028	3.10	0.23	601.98	0.43	0.54	99.52
2,029	3.10	0.23	504.43	0.44	0.55	85.92
2,030	3.10	0.23	422.98	0.44	0.55	74.23
2,031	3.10	0.23	354.97	0.45	0.56	64.18
2,032	3.10	0.24	298.18	0.45	0.56	55.55
2,033	3.10	0.24	250.77	0.46	0.57	48.13
2,034	3.10	0.24	211.17	0.46	0.57	41.76
2,035	3.10	0.24	178.11	0.46	0.58	36.29
2,036	3.10	0.25	150.50	0.47	0.59	31.59
2,037	3.10	0.25	127.45	0.47	0.59	27.56
2,038	3.10	0.25	108.21	0.48	0.60	24.11
2,039	3.10	0.25	92.13	0.48	0.60	21.15
2,040	3.10	0.26	78.71	0.49	0.61	18.62
2,041	3.10	0.26	67.51	0.49	0.62	16.45
2,042	3.10	0.26	58.15	0.50	0.62	14.60
2,043	3.10	0.26	50.34	0.50	0.63	13.02
2,044	3.10	0.27	43.81	0.51	0.63	11.68
2,045	3.10	0.27	38.37	0.51	0.64	10.54
2,046	3.10	0.27	33.82	0.52	0.65	9.57
2,047	3.10	0.27	30.02	0.52	0.65	8.75
2,048	3.10	0.28	26.85	0.53	0.66	8.06
2,049	3.10	0.28	24.20	0.53	0.67	7.49
2,050	3.10	0.28	21.99	0.54	0.67	7.01

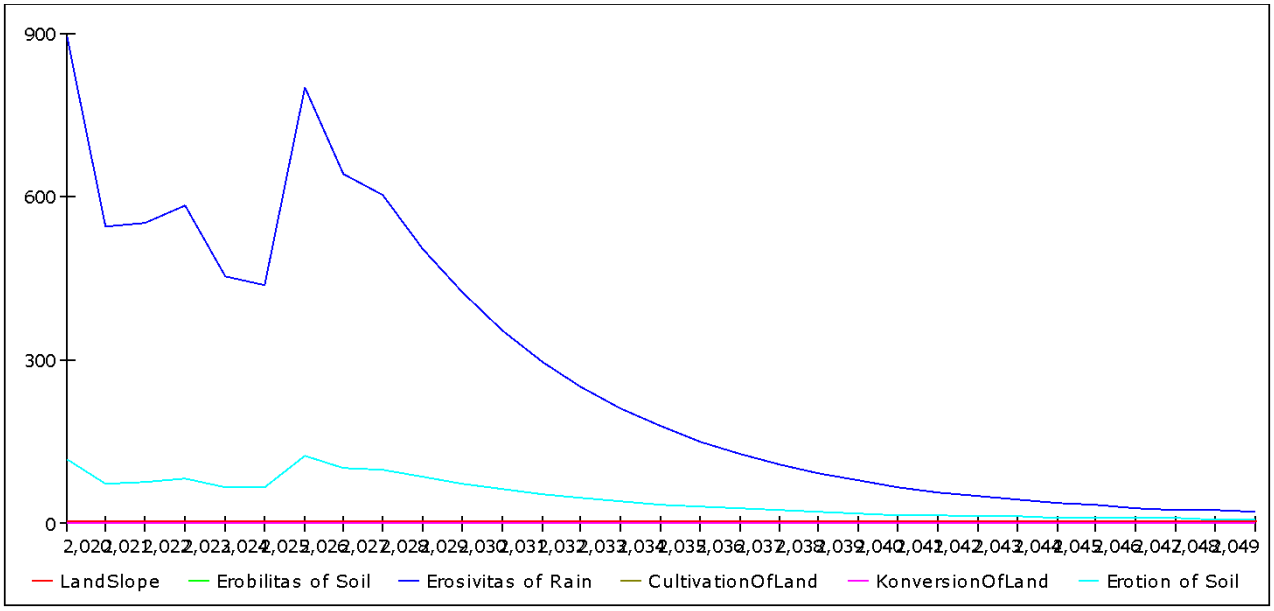

Figure 5. Pattern Simulation Of Erotion 2020-2050

4.2 Discussion

The simulation results are obtained with several assumptions taken, which can be a concern as a limitation in the analysis of the results shown above.

(a) Rainfall pattern is assumed to follow the pattern of rainfall in the last ten years. The simulation results show that rainfall is getting smaller and smaller in the lake area. On the one hand, this will be advantageous, because landslide erosion is predominantly influenced by rainfall, rainfall will carry or wash away soil material. But of course the predicted minimal rainfall is very worrying. One source of lake water is from rain.

(b) The pattern of growth rates for several variables, because the data from the Public Works Service which oversees the supervision of lakes and rivers, the Environmental Service, as well as from various previous research publications, have not found this variable rate. The variable rate is mainly the rate related to environmental changes, such as the rate of change in soil conversion, the rate of tillage, the rate of soil erosion in this study using the assumption of 1%. These variables will logically experience growth, along with population growth, and increased population activity, and improve the economy in the environment around the lake. The social relationship of population to the variable rate is real and logical, but very complex, and there is no theory that explains it.

5. CONCLUSION

Some conclusions that can be drawn from this research are:
1. Based on the simulation model made, it can be shown that the existence or sustainability of Buyan Lake is strongly influenced by the rainfall that occurs. Buyan lake is a caldera lake, whose water source is obtained from rain, and there are no other water sources.
2. Based on the 2010-2019 rainfall pattern, the rainfall pattern is very worrying, the peak area of the catchment area (catchment area) in the next 30 years is predicted to be a dry area, and this will greatly affect the condition of the lake.
3. Landslides in the next few years will not be a problem, because the main factor, rain erosivity shows a significant decrease.
4. Based on these conditions, the condition of the lake needs serious attention, although landslides are decreasing, the volume of lake water will certainly shrink.

ACKNOWLEDGMENTS

We would like to thank Ganesha University of Education, which has supported this research through DIPA research funding

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