Water Quality Index in Lake Maninjau as a Parameter to Determine the Optimum Economic Growth of Floating Net Cages and Land-based Livelihood

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Abstract: United States Environmental Agency defines pollution point sources and nonpoint sources pollution as follows: "The source of contaminants (pollutants) can be either a specific location (point source) or indeterminate / spread (non-point / diffuse source). Point source pollutant sources eg car exhaust, smokestacks and industrial waste channel. Pollutants emanating from the point source is local. The effects can be determined based on the spatial characteristics of water quality. Volume of pollutants from a point source is usually relatively fixed. Sources of non-point source pollution can be a point source in large numbers. For example, runoff from agricultural areas containing pesticides and fertilizers, runoff from residential areas (domestic). Meanwhile economic growth of Floating Net Cages (FNC) and land-based livelihoods in the basin Maninjau increase the income of local people but also increase pollution in the lake. Without proper watershed management, water quality will decline so would endanger the preservation of lakes and human health. The aim of this study was to determine the optimum value of the land-base and FNC economic growth based on threshold values of water quality index in the lake Maninjau. The method used to determine land use predictions using the Land Change Modeler (LCM). Patterns of land use change using the Land Change Modeler (LCM) revealed that in the area of Lake Maninjau affect the level of Water Environment Quality Index, in which the highest contribution of pollutants comes from FNC. Land use changes that occur in the area of Lake Maninjau have affected significantly the economic growth and environmental degradation. Changes of land use with a low value to a higher value has proven to improve productivity, thereby increasing the economic value, such as a change from forest to mixed farms, orchards mixture into a field, the field becomes settlement, as well as rice paddies turned into settlements. On the other hand, the use of land in a watershed with a variety of both residential and agricultural uses has donated contaminants which empties into the lake, causing the quality of the environment in each estuary is varied and has a steadily declining trend. Spatial modeling showed contamination levels touching bad condition in 2023. In that year the percentage of forest cover in the area of Lake Maninjau is still dominant, amounting to 21.78%, 20.74% mixed gardens and fields 7.77%, 3.94% rice, land up 2.07% and the open land of 0.001%, while the number of FNC many as 29 146 units, and the total economic value of 3 trillion rupiah region but has experienced a polluted condition. In 2023 the maninjau lake water conditions already in polluted conditions, so that economic activity related to water cannot continue.
Keywords: Maninjau, Land Use, WQI, Economic growth, LCM

Introduction

Lake Maninjau is a caldera with 9,738 ha (LIPI, 2001). Traditionally, the lake is utilized by local people as a source of clean water for daily needs and as a source of subsistence livelihoods in the inland fisheries sector. since 1983 the lake is becoming important locations theat get special attention at the national level since the establishment of hydroelectric power plant with a capacity of 68 M-Watts (PT PLN PERSERO, 2015).

Its watershed area is relatively narrow (23.434 ha) dominated by topography with steep slopes. Nevertheless, population growth has driven land use for the expansion of agricultural land as a land-based livelihoods. Lands with steep slope are maintained by changing landscape become cascading agricultural terraces mainly to rice fields. The expansion of agricultural land has also penetrated the forest area at the foot of a hill-ridge around the watershed. As a regional tourism destination, several facilities and infrastucture are also bulit in several strategic locations.

The limitations of the land led to the development of land-based livelihoods become saturated. In order to increase the income of local communities, the local government in cooperation with the National Science Agency started introducing the cultivation of pisciculture using Floating Net Cages (FNC). This innovation got tremendous response from the community so it is very fast growing.

Starting with 12 units FNC in 1992, within a period of 14 years has grown into 8,955 units in 2006 (Syandri, 2006). Agam District Development Planning Agency in 2014 reported that the FNC in Lake Maninjau has grown to become 21,608 units (Dinas Perikanan dan Kelautan, Kabupaten Agam).

Land utilization in agricultural and torism sectors as well as the growth of FNC have increased the income of local communities (Asnil, 2012). However, the increasing economic growth was followed by increasing pollution in Lake Maninjau (LIPI, 2001; LIPI, 2007; Elfrida et al, 2012).

Agricultural lands, which are managed very intensively, are the sources of the pollutants to the aquatic in the form of sediment, fertilizers and pesticide residues. Settlements and tourism facilities also became sources of polluters such as household waste and coliform bacteria. All the pollutants eventually accumulate in the body of the lake

Pollutants originating from the land mix with pollutants originating from unconsumed feed and excretion product of FNC. Without proper watershed management, pollution will increase so that it will endanger the sustainability of the lake and human health. Damage to the ecology of the lake also threatens the continuity of hydroelectricty Maninjau, which is a source of electrical energy to parts of Sumatera.

Marganof (2007) determines the level of pollution in the Lake Maninjau using water quality index based on National Sanitation Water Quality Index (WQI) by Ott (1978). The index provide a grade revealed the overall water quality at any given time. The advantage of this index is able to transform the complexity of water quality data into information that is easily understood and can be used by the public.

The purpose of this study is to determine the optimum value of land-based and FNC economic growth based on the threshold values in water quality index of the Lake Maninjau. The optimum condition is a state where changes in land use and growth of FNC generate economic benefits at the time of WQI grade is in the threshold of tolerance.

The Methods

This study was conducted by the following observations. (1) Land use change using serial of Landsat imageries years 1989, 2002, 2014. (2) FNC distribution and growth by year, (3) economical growth by year, (4) Water quality measurements.

Landsat image interpretation is done through a supervised classification approach using e-Cognition rule set with the mode of fragmentation and the differences in spectral multiresolution. The types of land use defined into four groups namely forest, agriculture (moor, mixed farms and rice fields), the region awoke (residential and open land), and water (rivers and lakes). (Zhou & Troy, 2008).

Prediction of land use is done by using the module Land Change Modeler (LCM) on TerrSet Idrisi software ver. 18.00.

Lake pollutant parameters measured are determined based on the parameters used to determine the Water Environment Quality Index (IMLP) developed by Ott (1978). These parameters consist of temperature, suspended sediment, turbidity, pH, dissolved oxygen (DO), BOD5, nitrate (NO3-N), phosphate (PO4-P), and fecal coli bacteria. Measurements carried out directly in the river estuary 19 points and 19 points in the body of the lake around FNC, with the coordinates is shown in Table 1 and Figure 1.

Table 1. GPS Coordinates of Measurement Points

No	Watershed	Estuary measuring point		FNC Measuring Point	
		X-GPS	Y-GPS	X-GPS	Y-GPS
1	Tj. Alai	100.1594	-0.2750	100.1601	-0.2756
2	K. Malintang	100.1630	-0.2690	100.1638	-0.2697
3	J. Ampang	100.1741	-0.2617	100.1750	-0.2634
4	T. Asam	100.1827	-0.2595	100.1831	-0.2600
5	K. Kaciak	100.1857	-0.2540	100.1870	-0.2557
6	Bt. Kalarian	100.1923	-0.2549	100.1919	-0.2565
7	S. Rangeh	100.2095	-0.2632	100.2093	-0.2642
8	B. Ligin	100.2144	-0.2711	100.2134	-0.2715
9	KJA3 Bayua	100.2177	-0.2762	100.2164	-0.2769
10	Bt. Maransi	100.2250	-0.2858	100.2241	-0.2862
11	Limau Sundai	100.2245	-0.3177	100.2239	-0.3177
12	KJA1 Mainjau	100.2241	-0.3227	100.2235	-0.3229
13	Maninjau	100.2212	-0.3333	100.2206	-0.3332
14	Tj. Sani	100.2148	-0.3583	100.2142	-0.3577
15	Tj. Sani 1	100.2139	-0.4003	100.2131	-0.4000
16	Tj. Sani 2	100.2006	-0.4009	100.2005	-0.4001
17	Tj. Sani 3	100.1862	-0.4006	100.1857	-0.3998
18	Sigiran	100.1669	-0.3509	100.1674	-0.3509
19	M. Terurai	100.1643	-0.3109	100.1654	-0.3112

Source : Survey

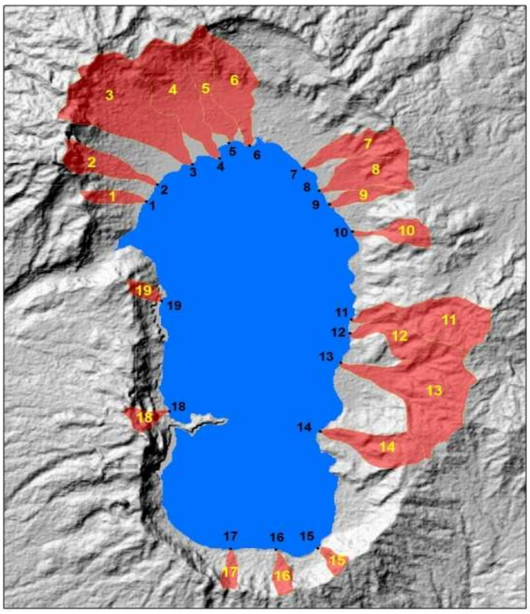

Figure 1. The points of measurement parameters of water pollution and Watershed Lake Maninjau: (1) Tanjung Alai, (2) River Malintang, (3) Bridge Ampang, (4) Tanjung Asam, (5) Koto Kaciak, (6) River Kalarian , (7) River Rangeh, (8) River Ligin, (9) FNC3

Analysis of water environmental quality index based method National Sanitation Foundation Water Quality Index (NSF-WQI) (Mahbud, 1990), by the equation:

$$IMLP = \frac{\sum_{i=1}^{n} W_i I_i}{\sum_{i=1}^{n} W_i} \qquad (1).$$

Description

WQI = index environmental quality of the lake waters, scale 0-100. Wi = constant weighting of the i-th, scale 0-1. Ii = Value of standard curve subindex i-th, scale 0-100.

The pollution load in tonnes per year selected to describe the relationship between the amount of land area with pollutant parameters are transferred to the lake. To change the unit of mg / L to ton / year used the equation (Soemarwoto. 2008).

$$BL_{DAS} = Q*C*a \qquad (2)$$

Where BLDAS = Load DAS waste (tons / year); Q = flow of the river at the mouth (m3 / s); C = concentration of pollutants in the estuary parameter (mg / L); a = constant (31.104). To calculate the amount of waste load derived from KJA activities carried out by the method of estimating the total organic material (Iwana, 1991 in Barg, 1992) by the equation:

$$O = TU + TFW \qquad (3)$$

Where O = total output of particulate organic material; TU = total feed that was not consumed and TFW = total waste of fish feces.

The economic value of agricultural land is the sum of all cultivated land use. FNC economic value is the sum total of the benefits derived from fishing activities FNC. Calculation of economic value using Cost Benefit Analysis (Gittinger, 1986) where the net benefits are in the form of profits

Result And Discussion

The changes of land use in Maninjau area in 1989 till 2050 showed the decrease of forest area significantly and additional of mix garden.

which is quite large. The forest which was in 1989 with 8.228,25 ha decrease rocketly. It is shown on the prediction result that it decrease to to be about 3.607,83 ha in 2050. The magnitude land decrease is for ± 5000 ha. On the contrary, The forest area and the mix garden increase rocketly. It was stated that the mix garden in 1989 was about

Tabel. 2. The changes of land use magintude in Maninjau Lake Area in 1989 to 2050

Year	Land (ha)						
	Forest	Field	Mix Garden	Bush	Rice/ Farm	Urban Solid	Urban Void
1989	8.228,25	1.786,41	1.791,63	856,98	962,55	173,43	12,42
2002	6.496,92	1.814,76	3.510,09	752,58	950,13	282,06	5,13
2005	6.231,33	1.808,19	3.769,20	742,68	946,62	310,14	3,51
2010	5.766,30	1.818,90	4.226,67	698,67	941,58	356,58	2,97
2014	5.472,27	1.815,93	4.517,19	666,81	933,66	402,93	2,88
2015	5.436,18	1.827,36	4.552,65	647,82	934,92	409,86	2,88
2020	5.190,21	1.829,88	4.797,54	602,01	931,41	457,74	2,88
2025	5.079,96	1.833,75	4.904,64	566,73	929,79	494,10	2,70
2030	4.795,29	1.843,11	5.182,29	529,83	925,11	533,43	2,61
2035	4.345,47	1.843,47	5.625,90	501,21	920,25	572,85	2,52
2040	4.009,77	1.849,86	5.953,77	472,32	914,76	608,76	2,43
2045	3.767,40	1.846,44	6.183,63	448,20	908,37	655,38	2,25
2050	3.607,83	1.839,87	6.326,91	426,60	902,25	705,96	2,25

Source : Data Processing Citra LandSat

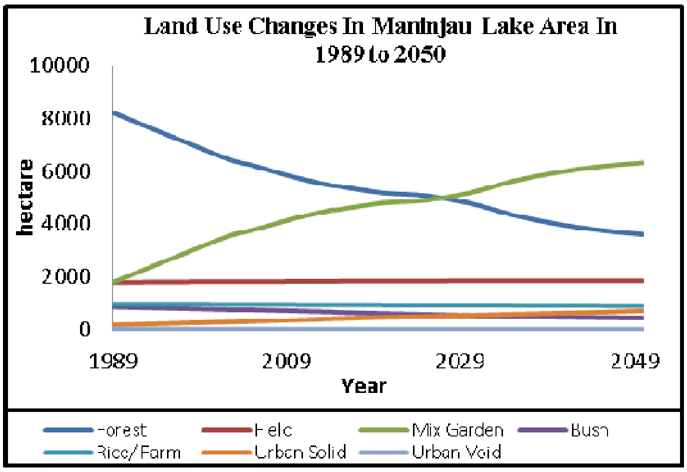

Figure 2. Land Use Changes In Maninjau Lake Area In 1989 to 2050

1.791,63 ha increase to be 6.326,91 in 2050. as well as the region woke up, fields, shrubs, fields and open land continues to change from year to year as presented in Table 2 calculate the water environmental quality index whose association with the type of land use of the debit, then for each watershed are grouped into three classes: (1) the forest; (2) consists of the agricultural fields, gardens mix, rice, and shrubs, as well; (3) the region woke up consists of settlements and open lands around settlements, Coefficient quality of the room is reflected by the runoff coefficient of different types of land use (Soemarwoto, 1992), with variations Similarly land use in a watershed will determine changes in river discharge.

Table 3. DAS Size, Land Use, and Debet at the River estuary

No	DAS	DAS (ha)	Forest (ha)	Agriculture (ha)	Urban Solid (ha)	Debit (m3/detik)
1	Tj, Alai	104,22	36,27	62,84	5,12	0,104
2	K,	255,33	110,49	139,89	4,95	0,129
3	J, Ampang	1015,11	449,62	523,08	42,41	0,199
4	T, Asam	610,11	226,11	371,46	12,54	0,168
5	K, Kaciak	294,75	91,80	195,19	7,76	0,141
6	Bt, Kalarian	471,42	168,62	295,37	7,43	0,153
7	S, Rangeh	289,35	111,14	174,25	3,96	0,130
8	B, Ligin	355,41	117,17	237,91	0,33	0,110
9	KJA3	115,74	33,67	62,93	19,14	0,132
10	Bt, Maransi	170,64	88,43	80,39	1,82	0,107
11	Limau	565,38	346,07	217,24	2,07	0,151
12	KJA1	247,23	130,02	114,90	2,31	0,121
13	Maninjau	960,48	600,79	354,25	5,45	0,179
14	Tj, Sani	339,48	213,00	122,02	4,46	0,145
15	Tj, Sani 1	64,62	46,09	18,29	0,24	0,066
16	Tj, Sani 2	90,09	63,91	25,99	0,20	0,074
17	Tj, Sani 3	69,21	47,88	20,67	0,66	0,078
18	Sigiran	89,01	63,45	25,33	0,23	0,076
19	M, Terurai	67,95	20,70	46,76	0,50	0,063

(Source : Data Processing, 2015)

The linear relation between independent variable (Xi) including the size of DAS, Forest, agriculture, urban solid, and river debet are formed through multiple linear regression equation.
The River debet (Q) at the estuary has relation with DAS size (X1), the large of land use (X2), agricultural (X3), and urban solid (X4) are as following formula :
$Q = 0,056*\ln(X1) – 0,00068*\ln(X2) – 0,027*\ln(X3) + 0,000997*\ln(X4) – 0,0674$ ……………..… (4)

As the result of multiple linear regression equation is $R2 = 0,903$ which means the debet fluctuation has linear relation with DAS size, forest, agricultural, and urban solid for about 90,3 %. Based on the measurement at the 19 river estuary, each pollutant indicator mostly meet the requirement of the water quality class 1 as per stated on PP No. 82 in 2001. The quality of estuary water mostly meet the requirement of water substance analysis class 3 (PP No.82 in 2001) which is consider as freshwater fish cultivation area, husbandry, corps irrigation, and/or for another functions to reach the requirement of water quality as well its function.
The weight of land pollution measured at the estuary is consist of TSS TSS, BOD5, NO3-N, PO4-P, and fecal coli. To calculate the weight of land fecal coliform is formed by fecal coliform concentrate times debet and the result is MPN/second.

Table 4. The result of Pollutant indicator at the river estuary

No	DAS	Temperature (^oC)	TSS (mg/L)	Turbidity (JTU)	pH	DO (mg/L)	BOD_5 (mg/L)	PO_4-P (mg/L)	NO_3-N (mg/L)	F-coli (MPN/ 100mL)
1	Tj, Alai	27,70	65,40	17,84	7,63	5,71	5,34	0,33	0,24	31,49
2	K,	27,95	53,67	14,38	7,75	5,65	5,16	0,33	0,28	31,48
3	J, Ampang	28,24	50,70	13,85	7,92	5,26	6,72	0,47	0,36	32,50
4	T, Asam	28,05	53,64	14,41	7,85	5,46	5,84	0,45	0,35	32,00
5	K, Kaciak	28,05	60,00	15,28	7,90	5,47	5,74	0,38	0,28	31,70
6	Bt, Kalarian	27,80	55,48	14,69	7,82	5,63	5,62	0,42	0,30	31,53
7	S, Rangeh	27,91	56,32	14,79	7,70	5,69	5,12	0,39	0,28	31,44
8	B, Ligin	27,80	60,46	18,13	7,62	5,72	4,82	0,40	0,29	31,25
9	KJA3	27,90	63,02	18,47	7,89	5,49	5,27	0,30	0,28	32,25
10	Bt, Maransi	27,80	57,09	14,77	7,42	5,75	4,92	0,31	0,27	31,10
11	Limau	27,86	54,52	15,44	7,41	5,86	4,95	0,39	0,28	31,14
12	KJA1	27,71	57,96	15,87	7,67	5,71	5,12	0,32	0,27	31,37
13	Maninjau	28,00	50,14	15,04	7,77	5,45	5,43	0,43	0,34	31,50
14	Tj, Sani	27,87	54,86	14,37	7,84	5,54	5,12	0,32	0,28	31,47
15	Tj, Sani 1	27,58	61,90	18,05	7,21	6,27	4,18	0,25	0,15	30,67
16	Tj, Sani 2	27,80	64,60	17,36	7,40	5,89	4,53	0,27	0,23	30,52
17	Tj, Sani 3	27,68	65,31	17,46	7,25	6,13	4,36	0,29	0,21	31,00
18	Sigiran	27,73	63,80	17,27	7,31	6,10	4,02	0,23	0,21	30,62
19	M, Terurai	27,60	72,00	19,76	7,34	6,03	4,34	0,26	0,23	30,98

(Source : Site Survey, 2014)

Based on the data on table 8 above, it is shown that water quality at the estuary reach the WQI value about 68,75 (average). This illustrates that the water quality at the estuary in 2014 was in contaminated/ polluted condition.

Table 5. Water Quality at the estuary

	Debet (m3/det)	**IMLP**	**Weight of Pollutant (ton/year)**				**F,coli (MPN/det)**
			TSS	**BOD_5**	**PO_4-P**	**NO_3-N**	
Maximum :	0,199	71,55	314,30	41,66	2,91	2,23	64.774,77
Minimum:	0,063	65,51	127,90	8,45	0,51	0,31	19.386,82
Average :	0,122	68,75	218,96	20,04	1,38	1,08	38.577,51

Source : Processing Data, 2015

The comprehensive primer data was used for Pollutant indicator calculation purpose at Maninjau lake in 2014. The measurement result of previous research and the result of spatial interpolation for the previous years were done through spatio-temporal statistic approach. The data taken after 2014 was the interpolation result through spatial statictic approach. This approach required all the data in every measurement coordinates for interpolated purpose.

Therefore, it is required to get a knowledge pertaining the relation of each indicators as the basic to determine the interpolated value.

Table 6. The relation between Pollutant Indicator at the river estuary

Indicator	Regression equation	Determinated coefficient (R^2)
Temperature (T)	$T = 33{,}881*(DO)^{-0{,}113}$	0,752
Turbidity (Tb)	$Tb = 0{,}2786*(TSS)^{0{,}9962}$	0,801
Acidity (pH)	$pH = 23{,}823*(DO)^{-0{,}654}$	0,901
Dissolved Oxygen (DO)	$DO = 9{,}9168*(BOD_5)^{-0{,}34}$	0,873
Suspended Sediment (TSS)	$TSS = 93{,}049*(\text{Hutan})^{-0{,}099}$	0,862
BOD_5	$BOD_5 = 4{,}7361*(\text{Lahan terbangun})^{0{,}0729}$	0,839
Phosphate (PO_4-P)	$PO_4 = 0{,}1393*(\text{Lahan Pertanian})^{0{,}1899}$	0,895
Nitrat (NO_3-N)	$NO_3 = 0{,}1151*(\text{Lahan Pertanian})^{0{,}1899}$	0,830
Fecal coliform	$FC = 31{,}1*(\text{Wilayah terbangun})^{0{,}0098}$	0,886

Source : Processing Data, 2015

The development of KJA around Maninjau Lake has increased the indicator concentrate, especially on the wasted fish feeding and fish feces. Syandri (2006) stated that there were only 70 % of feeding cunsumed, the rest 30 % flew into the lake estuary which was consideres as pollutant or waste. Avnim added that it was about 15-30 % of nitrogen (N) and phosphor contained in the feed would be retension to the flesh of fish. And the rest is flown to the lake estuary. According to Midlen and Redding (2000), in the estuary, 10 % of Phosphor (P), and 65 % of Nitrogen dissolved the flesh of fish, while phosphor (P) 65 % and Nitrogen (N) 10 % in the form of particle.
Referring to the result of site survey, the average of feeding for every KJA is about 25 kg/day with the total of N dissolved amounting 4.853,26 ton/ year, dissolved P 39,95 ton/year, Particle N 745,66 ton/year, and particle P 259,64 ton/year. Noted that the total of KJA calculated was 21.068 units.
The calculation shows the significant variance on each pollutant indicator concentrate at the estuary around KJA (refert to Table 7).

Table 7. The result of Pollutant Indicator Parameter at FNC

No	DAS	KJA (Unit)	Temperature (^oC)	Turbidity (JTU)	pH	DO (mg/L)	TSS (mg/L)	BOD_5 (mg/L)	NO_3-N (mg/L)	PO_4-P (mg/L)	F-coli (MPN/ 100mL)
1	Tj, Alai	438	28,31	15,79	8,25	5,00	54,00	7,94	0,52	1,67	78,95
2	K, Malintang	655	28,20	16,59	8,11	5,07	60,60	7,20	0,90	2,07	80,82
3	J, Ampang	515	28,21	15,11	8,31	4,90	55,18	7,48	0,93	1,52	79,48
4	T, Asam	84	28,09	11,57	8,24	5,25	44,00	6,51	0,17	0,31	73,71
5	K, Kaciak	316	28,20	14,79	8,13	5,18	55,55	6,76	0,74	1,50	77,65
6	Bt, Kalarian	451	28,22	15,88	8,26	5,05	58,00	7,29	0,75	1,55	78,84
7	S, Rangeh	278	28,13	13,65	8,06	5,19	51,00	6,70	0,62	1,26	76,71
8	B, Ligin	294	28,14	15,06	8,13	5,22	55,00	7,18	0,60	1,22	77,89
9	KJA3 Bayua	1116	28,41	16,94	8,46	4,75	61,00	8,72	1,18	2,55	82,08
10	Bt, Maransi	26	27,95	10,31	7,82	5,50	41,25	4,08	0,18	0,32	74,31
11	Limau	219	27,85	13,97	7,83	5,51	49,83	6,32	0,59	1,04	77,47
12	KJA1	424	28,24	15,74	8,42	5,06	57,50	7,25	0,72	1,27	79,05
13	Maninjau	698	28,33	15,75	8,40	4,92	57,52	7,85	0,80	1,97	80,50
14	Tj, Sani	768	28,30	16,70	8,60	4,87	61,91	8,10	0,98	1,90	80,28
15	Tj, Sani 1	24	27,73	10,28	7,85	5,58	37,48	4,15	0,32	0,61	69,97
16	Tj, Sani 2	308	28,14	15,24	8,24	5,17	52,00	6,79	0,62	1,19	77,80
17	Tj, Sani 3	102	27,90	13,33	7,68	5,71	48,65	5,43	0,35	1,13	70,20
18	Sigiran	254	27,86	15,79	7,74	5,65	54,00	5,23	0,56	0,68	77,18
19	M, Terurai	419	28,06	15,21	8,09	5,07	54,00	6,62	0,72	1,49	78,80

Source : Result of Data Processing

Likewise the measurement of pollutant indicator at the estuary was done in 2014 and the data of the previous years was taken from the measurement result of the previous research. The data of the spatial interpolation result was done through spatio-temporal statistic approach. While the data taken after 2014 was from the data of intepolation result via spatial statistic approach. This approach required all the data of every coordinates measurement to be interpolated. Therefore, the relation of each indicator is required as the basic to determine the interpolated value. (Table 8)

Table 8. The relation of each pollutant indicator at the lake / FNC

Indicator	Regression Equation	Determinated Coefficient (R^2)
Temperature (T)	Temperature, = $34{,}054(DO)^{-0{,}116}$	0,871
Turbidity (Tb)	Turbidity = $0{,}19(TSS)^{1{,}0931}$	0,942
Acidity (pH)	pH = $20{,}565(DO)^{-0{,}564}$	0,873
Dissolved Oxygen (DO)	$DO = 7{,}851(BOD_5)^{-0{,}22}$	0,743
Suspended Sediment (TSS)	$TSS = 26{,}524(KJA)^{0{,}1224}$	0,932
BOD_5	$BOD_5 = 2{,}3797(KJA)^{0{,}1818}$	0,847
Phosphate (PO_4-P)	$PO_4 = 0{,}0791(KJA)^{0{,}4807}$	0,761
Nitrat (NO_3-N)	$NO_3 = 0{,}0459(KJA)^{0{,}4525}$	0,809
Fecal coliform	$FC = 62{,}734(KJA)^{0{,}0375}$	0,812

Source : Result of Data Processing

The changes of aquatic pollutant level at the estaury river of Maninjau Lake use WQI in 1989, 1992, 2002, 2014, and 2050 as shown on the Table. 9. It presents that the quality of water lake at the river estuary in 1989 was considered good or uncontaminated. Unfortunately, this situation has kept decrease to 2050.

Table 9. The changes of WQI Value at the estuary

	IMLP (Year)					
	1989	1992	2002	2014	2025	2050
Makximum:	74,67	72,53	71,55	71,55	70,74	70,09
Minimum:	70,29	66,68	66,29	65,51	65,59	64,86
Average:	71,97	69,60	69,14	68,75	68,47	67,81

Source : Result of Data Processing

The significant illustration can be seen between the WQI value at the estuary with the changes aquatic pollutant level at the lake or around KJA. WQI value at the lake/around FNC (Table 10) is lower than WQI value. It presents that the pollution level of the lake around FNC is higher than the pollution level around the estuaries.

Table 10. The Changes of WQI Value at the Lake/ FNC

	IMLP (Year)					
	1989	1992	2002	2014	2025	2050
Makximum:	74,67	72,53	70,60	66,05	61,20	53,28
Minimum:	70,29	66,68	58,90	50,17	39,46	34,91
Average:	71,97	69,60	65,87	60,37	49,10	44,77

Source : Result of Data Processing

Based on the location, the tendency of the decrease of aquatic quality at the lake / around FNC is much higher than around the estuary. It can be seen the good quality of aquatic at the lake/ around FNC in 1989 has been slowly contaminated to 2050 (Refer to the picture 5)

Additionally, the significant decrease of aquatic quality of Maninjau Lake is due to the residue of fish feeding and fish feces flown into the lake which are considered as the main source.

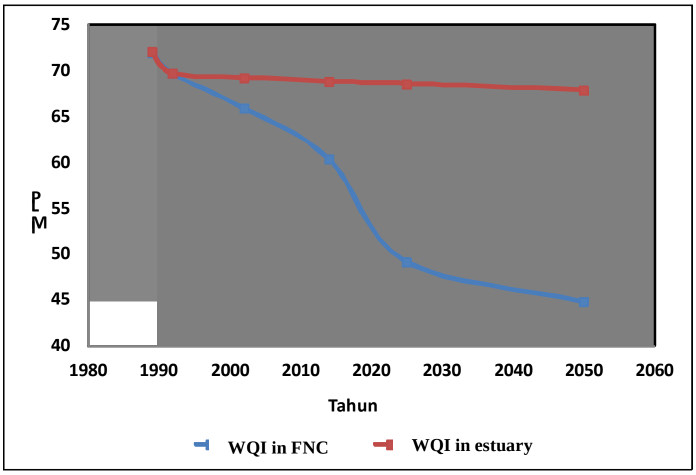

Figure 3. The Changes of WQI Value at FNC and Estuary

WQI value obtained from each measurement point interpolation using spatio-temporal statistical approach, The interpolation of these values is presented in Figure 5. Land use is year 2023 shown in Figure 4, the distribution of land use in the area of Lake Maninjau.

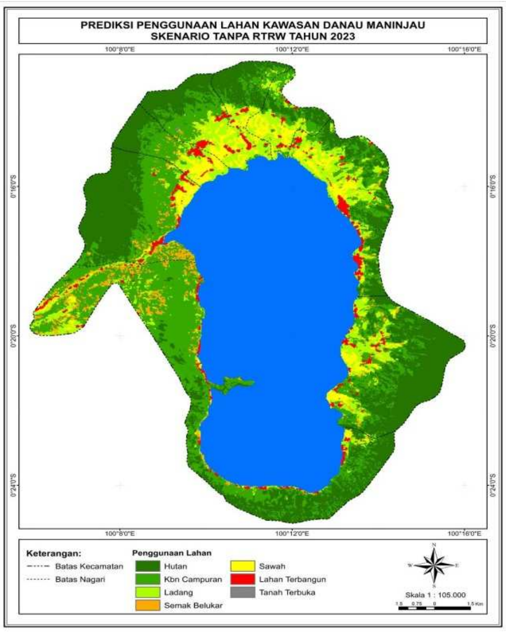

Figure 4. Prediction of Land Use Region Maninjau Year 2023

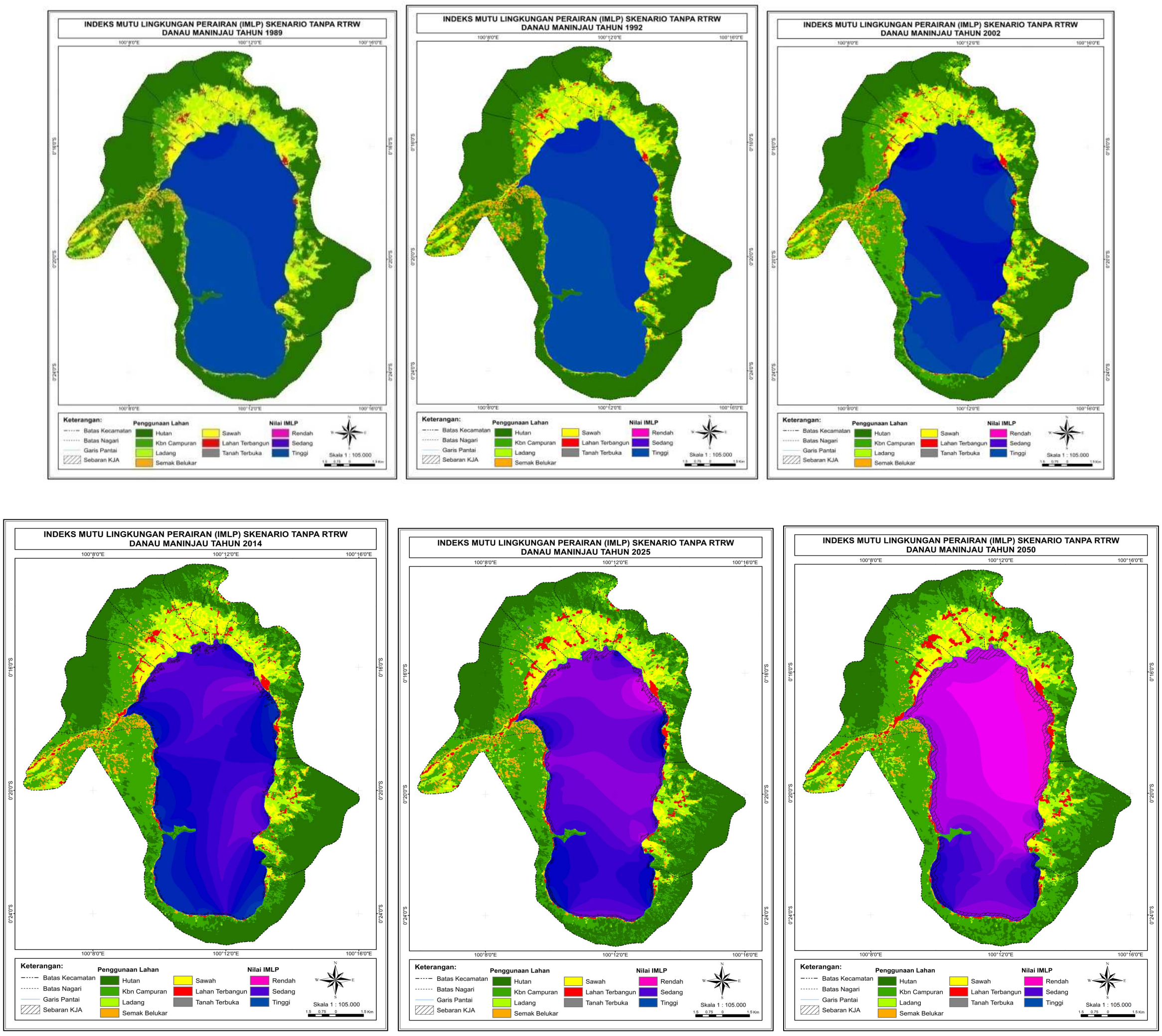

Figure 5: Map Interpolation of The Value WQI

Calculation of Total Economic Value is the sum of Economic Value of Direct and Indirect Economic Value. So the economic value obtained as shown in Table 11.

Table. 11. Total Economic Value

Year	Total Value To Direct (Milion Rupiah)	Total Value To Indirect (Milion Rupiah)	Total Economic Value (Milion Rupiah)
1989	292,97	4,80	297,77
2002	862,21	4,71	866,92
2014	2.277.222,00	5,27	2.277.227,27
2025	3.110.235,00	6,04	3.110.241,04
2050	5.380.226,00	8,04	5.380.234,04

Source : Result of Data Processing

Results of the analysis of value in order to direct and indirect use values show a very sharp economic growth, namely in 1989, when before the FNC activities in the area of its . Total Economic Value Maninjau of ± 300 million. However, after the advent of economic activity in Lake Maninjau FNC in the region's economic growth showed a very sharp growth rate, and until 2014 Total Economic Value Maninjau Lake Region recorded at ± 2.3 trillion. This figure continues to increase in accordance with the rate of change of land use and increase the number of units FNC. Until 2050 Total Economic Value recorded area of Lake Maninjau is of ± 5.5 trillion. Total Economic Value growth rate can be seen in Figure 6.

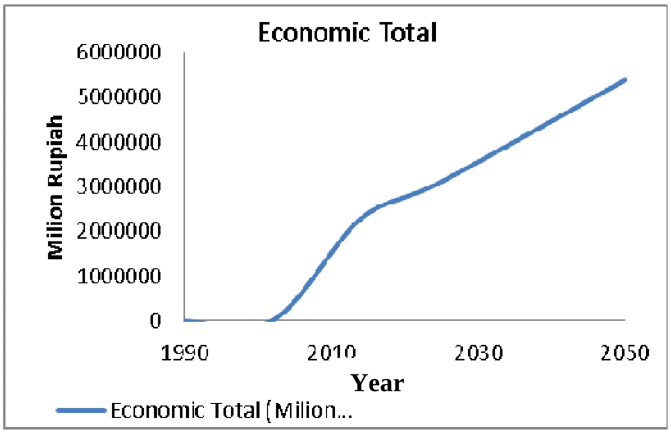

Figure 6. Graph Total Economic Value Maninjau Lake Region From 1989 To 2050

Acknowledgement

Land use changes have affected WQI trend continues to decline. This analysis shows that the territorial waters of Lake Maninjau will experience pollution saturation point in 2023, ie within a period of 8 years to come (2015-2023), in which the value IMLP touch the figure of 50, which means the condition of lake water in case of polluted / bad , In 2023 the percentage of forest cover in the region of Lake Maninjau is still dominant, amounting to 21.78%, 20.74% mixed gardens, fields 7,77%, rice 3.94%, 2.07% and undeveloped land and open land 0,001 % with the spatial distribution of land use. While the FNC unit in 2023 is as much as 29 146 units. Conditions of land use in 2023 could be a reference in managing the stability of the level of pollution in the region of Lake Maninjau. Along with the changes of land use, then the average value WQI in 1989 amounted to 71.97, this figure informs that the water of the lake is in good condition. In 1992 the next lake water conditions decreased to 69.60, indicating that the lake is a condition of being contaminated. In 2002 IMLP values continue to fall to 65.87, while 2014 was 60.37, the value is still in the range of contaminated medium. Based on the prediction of land use and calculation WQI fore continue to decline until the year 2023 hit a 50, which indicates the condition of the lake water was contaminated. If not applicable, then the reduction in 2050 into a 44.77 WQI value, this value informs that the lake water is already in very bad condition.

The effects of environmental pollution will directly reduce economic factors notably FNC is highly dependent on the stability and quality of the lake water. Economic growth FNC, and agricultural land; rice, mixed farms and fields; and the region woke up in the form of tax object selling value. The estimation results of the utilization of the total economy is based on changes in land use was obtained a value of Rp. 298 million in 1989, Rp. 867 million in 2002, Rp. 2.3 trillion in 2014, Rp. 3.1 trillion in 2025 and Rp. 5.4 billion in 2050. For the optimum value of economic growth in 2023 was about 3 trillion.

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