A dynamic model for sustainable utilization of water resources in Way Sekampung, Lampung Province, Indonesia

[1]Mirza Nirwansyah, [2]Cecep Kusmana, [2]Eriyatno, [2]Mohamad Y. J. Purwanto

[1] Doctoral program of Environmental Studies and Natural Resources, Bogor Agricultural University, Bogor, Indonesia; [2] Post Graduate School, Bogor Agricultural University, Bogor, Indonesia. Corresponding author: M. Nirwansyah, nirwans62@yahoo.com

Abstract. Water is a vital resource for human life. Thus, by developing the management and the utility of water resources that can meet the demand of humans need, it is purposed to maintain the nature balance so the water resources can be utilized sustainably. There are two items becomes the focus of the present research i.e. sedimentation and water balance. These factors are considered as the most important factors in planning a dam. The sustainability of water resources in Way Sekampung is identified by three main indicators: ecologic, economic and socio-cultural by using the Dynamic Model. Dynamic model is an excellent method to manage water resources. Recommendation and activities on dam planning, building and operating are important values to be used for the future of dam planning.
Key Words: dam, environmental, policy, water balance, sedimentation.

Introduction. Dam is a constructed facility of reservoir which provides substantial benefits to society. Conversely, a dam can also demonstrate incident of failures which mainly are caused by the internal and external factors. The internal factor is mostly caused by the sediment spill that known as siltation meanwhile the external factors such as highly risk of soil erosion, seismic activity and/or flash flood is considered. The primary step to prevent these problems is to acknowledge the causes of the failures which become a significant factor in order to improve engineering and construction management services for dams (Arsyad 2010). In order to enjoy the benefits of the water resource utilization, there is a need to engage communities on dam safety therefore some activities are necessary that relate to the management of water use (Fauzi 2014). In order to improve the management of dam, the procedures of dam maintenance are needed to be practiced such as regular inspection of the structure and the water volume of the reservoir (Marimin 2004). The dam of Way Sekampung purposes is mainly to provide irrigation water which secures the supply of 56.000 ha land, which becomes the irrigation land under central jurisdiction. The main issue of this land is the drought in the dry season even though the dam of Batutegi in Lampung Province has been operated but the major problem of freshwater demand is still in distress (Asdak 2010).

Material and Method. The research is taken in the research site of constructed dam of Way Sekampung in Pringsewu sub-district in Lampung Province which lays down Seputih Sekampung river. The research lasted for eight months, started from August 2017 until March 2018.

Data collection. The primary data of the research consisted of the measurement data recorded at the research site such as rainfall data, sedimentation rate, flood and drought. The secondary data was taken from several sources like: several research papers of Province and Sub-district Government, the system and policy data from the Major River Basin Organization (Indra et al 2004), and some analysis data from the Development Planning Agency (Budi 2008).

Data analysis. The water supply at certain area depends on the rainfall that directly influences the watershed. The size of water resource has the potential to affect the change of land use. One of several factors that damage the ecosystem in Way Seputih Sekampung is the decrease of the environmental support due to the stress of land use and lack of conservation effort done by the society (Ridwan et al 2014). The change of land-use has shown significant shift from agricultural sector to human-built area, industries and others. The observation of land change using GIS has been done for 20 years (1996 to 2016) as shown on Figure 1.

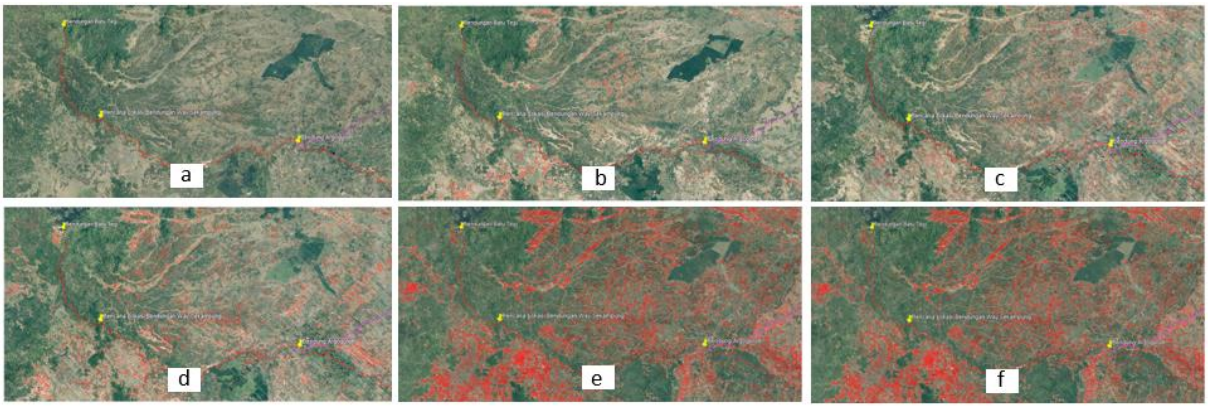

Figure 1. The change of land allocation in Way Sekampung.

The land-use shown in Figure 1a-d are the original area for the 1996-2008 period, but the Figure 1e and 1f show the changes of land-use in 2009-2016. The analysis of water supply and management is performed by the water balance appreciation to find out the condition of potential water that can be utilized without damaging its preservation. The model of this analysis is performed by comparing the maximum limit of the water supply (including the potential water) with the present use (included in the plan) to serve the socio-economy activity and its integral support the demographic growth. The researchers calculate the present water supply based on the rainfall data and/or the streamflow data and confront it with the water demand of the reservoir that has specific functions for example for hydroelectric power, irrigation and raw water. The researchers compare the amount of water that coming into the reservoir so called inflow with the amount of water that coming out so called outflow and evaporation of the reservoir inundation. The storage will be positive if the inflow show the higher amount of water than the outflow and evaporation, and the storage will be negative if the inflow is smaller than the outflow and the evaporation which causes the loss volume of storage. The water balance can be formulated as follow:

$$\text{Inflow} = \text{Outflow} + \text{Evaporation} : \text{A Storage}$$

The analysis of sedimentation and the utilization of the inundated perimeter are performed by investigating the demand of the reservoir volume and also the sediment rate, measured by Topographical Map, and the process of data collection is uses GIS program. This method is used to calculate the sedimentation rate which generally used to estimate the sediment rate of the river based on the empirical equation. This method will predict the ad-hoc calculation of the amount of gross erosion (Rizal 2012). To determine the amount of sediment that reaches to the research site, the gross erosion must be multiplied with the ratio of the sediment release and the sub model of water balance. Moreover, the researchers formulate the problem that occurred to reach the volume of the reservoir demand which has the optimal support system of dam function. Therefore, the researchers use the formula of USLE, a model to predict erosion of a land which been described by Wischmeier & Smith (1965, 1978). USLE guides the planner to predict the average rate of erosion on a cultivated field which has a steep slope. It shows the actual result of sediment rate, thus by using the existing model, the researchers obtain the information of the volume of sediment associated with the year T and the service life of the dam also it describes the effective volume of reservoir in line with the achieved-result of its function.

Dynamic model. The Dynamic Model analysis is to solve the complex problems, concerning the system approach, using the concept of the dynamic system model. The stimulated model will give the solution of the real problematic complexity. Dynamic system analysis is starting with determining goals in the system (Sterman 2004). This was conducted by finding out the requirements of the systems, all the problems encountered during the study were defined; the problems were thoroughly deliberated upon. The problems encountered in the system, served as constraints in the effectiveness of the system. The next stage had to deal with identification of the problems and this was done by creating a causal relationship diagram between the input and the output variables (Causal Loop Diagram). The causal loop functions in a way limit the system (Muhammadi et al 2001). Technical analysis was conducted by building a structure (Stock Flow Diagram) that was used to perform simulations, where data grouping and data input were carried out in the model structure (Firmansyah 2015). This helped to closely monitor the behavior of the system. Validation was conducted in order to be accounted as scientifically. System behavior can be deduced from the factors/variables in the model using either the quantitative or the qualitative factors (Firmansyah 2015). Model evaluation was conducted by comparing the output of the scenario simulation during the system identification stage with the analysis result of water availability and crop water demand. The sensitivity test was carried out from the simulation and from the risk of applying the scenario to the policy that would be implemented. The stages of the dynamic system developed in the present study are represented in Figure 2. This is an excellent analytical method, designed to be used for both short and long term. This is because it can be used to deduce the conditions that cause changes in the behavior and abstract relationships of the causal loops. This study was limited by some assumptions such as time, and the amount of data in the time series were not enough to produce a good model (Firmansyah 2015).

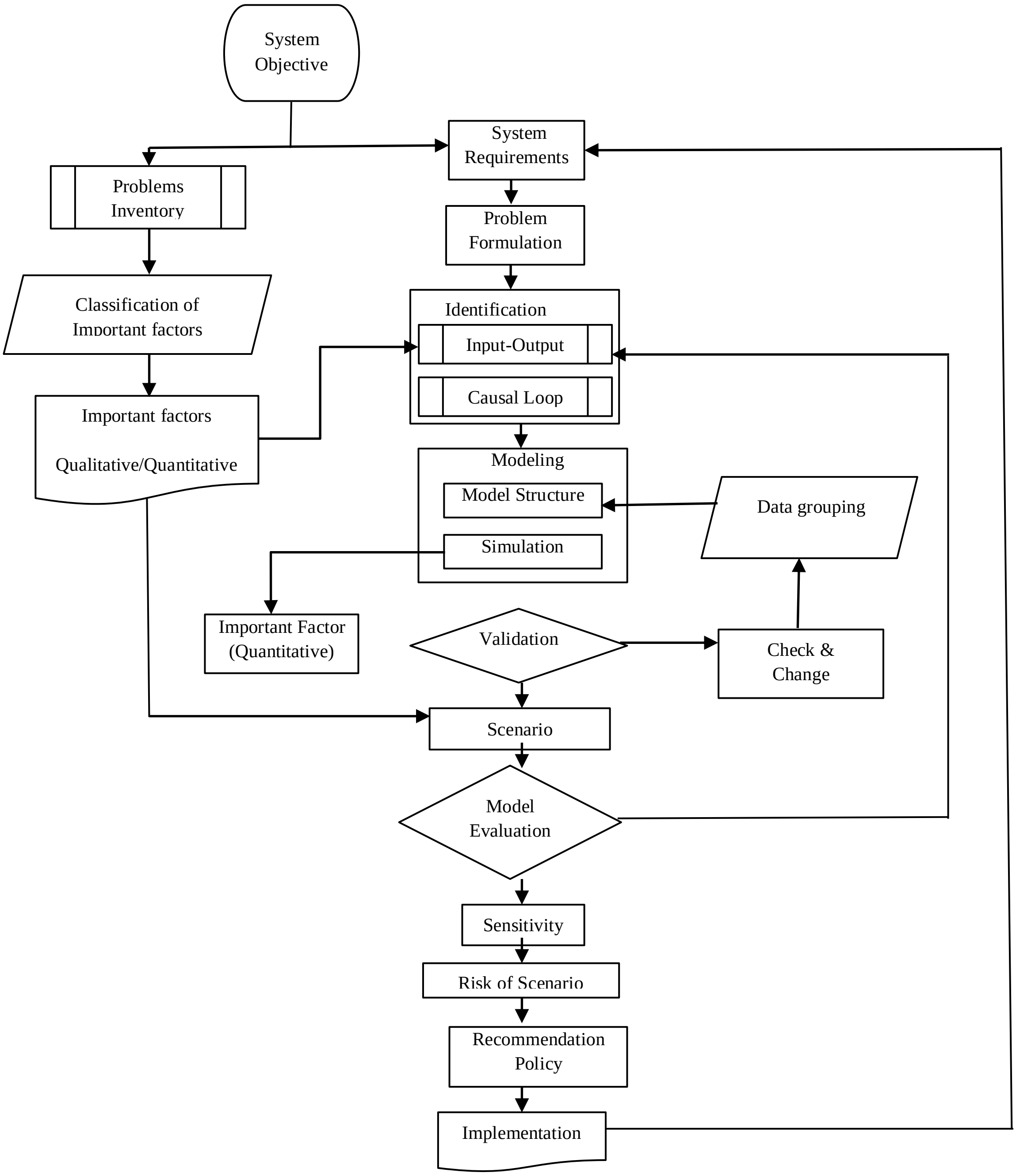

Figure 2. Dynamic System stages (Eriyatno 2003).

System requirements. An inventory consisting of government stakeholders, communities and business owners were taken at this stage. This was done using a checklist assessment text, that was conducted in order to qualitatively and quantitative assess the level of importance of each stakeholder. The use of factors and their level of importance were obtained from the results gotten from brainstorming and the analysis carried out by the researchers which were verified again by the stakeholders at the study location.

Problem formulation. There was conflict of interest among the stakeholders, and this was a problem that needed to be resolved immediately, so that the system could work constructively in achieving its objectives. The solution was carried out by identifying the existing problems of each stakeholder and their influences on each other. The formulation of the problems was obtained from the variables in the needs analysis.

System identification. System identification allows examining the actual system state. This is done by identifying the initial and fundamental issues, after which an alternative solution to the problems was deduced. Generally, there are six groups of variables that affected the performance of the system, namely: (1) the wanted output variable, this was determined based on the main objectives in the system; (2) unwanted output variables; (3) controlled input variables, which were obtained from important factors based on the needs analysis; (4) uncontrolled input variables; (5) environmental input variables and (6) the system control variables (Manetsch & Park 1977; Hardjomidjojo 2007). In the technical development, the causal diagram above was used as a basis for creating a flow diagram, the SFD (Stock Flow Diagram) which was simulated by using the Powersim Studio 10 program. This provided an overview of the systems' behavior. The result can be said to be the best alternative for the system being studied. After that, analysis was performed in order to get conclusions, and the policies that should be implemented in order to change the behavior of the system according to the wanted output. Causal loop diagram, was used as a model of control for the conversion of the rice field (Firmansyah 2016) and this was done in order to observe the economic growth, increased economic activities in the agricultural sector, the ease of labor, reduced number of unemployment and all these caused the poverty level to have a positive impact on the existence of the rice fields on the location. Demographic growth, led to an increased demand for residential space. Other activities also have an impact on the reduced availability of space due to field conversion (agriculture and forest areas) and the procurement of public facilities and infrastructure. The relationship between these variables was formulated in the form of mathematical equations. The effect of causal relationships on the field use was seen based on the correlation data that was derived from changes in the field use.

Model simulation. The simulation results obtained from the dynamic system modeling were used to observe the patterns of tendency for the model behavior (Hartisari 2007). They were then analyzed and traced to the factors that led to the trend in the pattern, and this explained how the mechanism occurred based on the analysis of the model structure (Hassan Pourfallah et all 2015).

Model validation. Model behavior validation was done by comparing the magnitude and the nature of the errors (Muhammadi et al 2001), namely: 1) Absolute Mean Error (AME), which is the deviation (difference) between the average value (mean) of the simulation results and the actual value; 2) Absolute Variation Error (AVE), which is the deviation of the simulation variance against the actual variance. The limit of acceptable deviation is <10%.

$$AME = [(Si - Ai)/Ai]$$

Where:
Si = Si N, where S = simulation value
Ai = Ai N, where A = actual value
N = observation time interval

$$AVE = [(Ss - Sa)/Sa]$$

Where:
$Ss = ((Si - Si)^2 N)$ = deviation of simulation value
$Sa = ((Ai - Ai)^2 N)$ = deviation of actual value

Result and Discussion. Hydrology data that been analyzed in calculation of dependable flow is the river streamflow of Way Sekampung based on the streamflow data accessed from the records of Batutegi Dam from 2002 until 2014 which have been measured based on the streamflow data average of 15 days. Meanwhile, if a massive streamflow or a small streamflow occurs, the researchers need to find out Q-average and Q80 from 1 January until December. The catchment area of Bendung Argoguruh is 2,200 km^2 meanwhile from its headwaters, the dam of Batutegi of a 424 km^2 lays down but the plan of the dam of Way Sekampung has only 346 km^2. The catchment areas are plotted as follow (Figure 3):

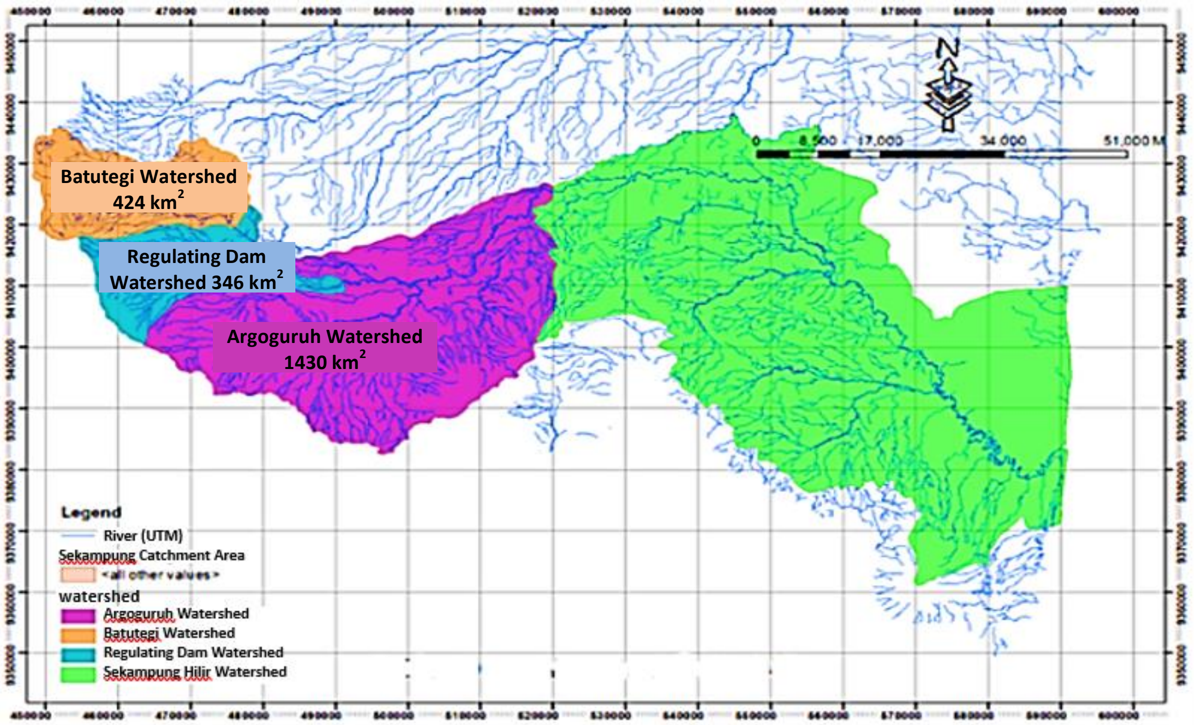

Figure 3. Map of the catchment area of Way Sekampung (BBWS-MS 2017).

Based on the analysis of water demand resulted the amount of streamflow that is required for daily needs so the water balance of Way Sekampung can be presented in Figure 4.

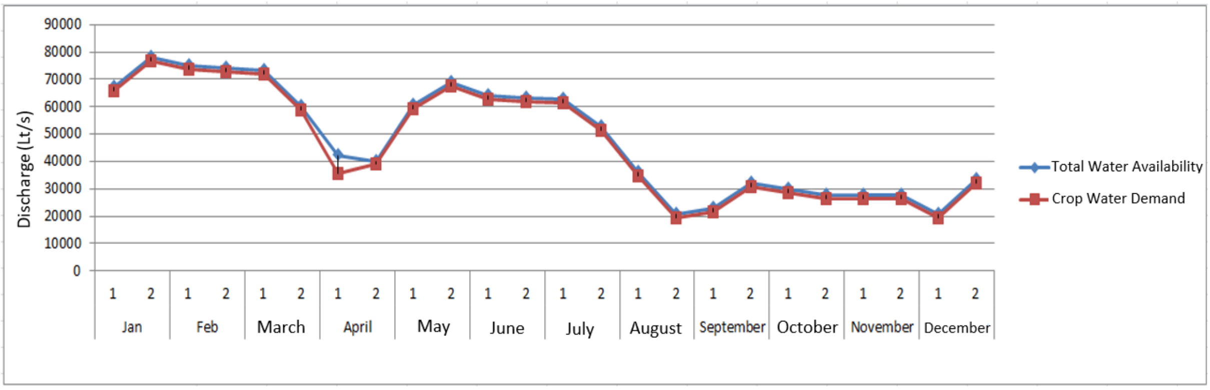

Figure 4. The water balance of Way Sekampung.

To obtain the streamflow of Way Sekampung dam with the catchment area of 346 km^2, the resulted calculation of streamflow of Bendung Argoguruh with catchment area of 1776 km^2 was converted with the comparison of catchment area as follow:

$$Q = Q1776 \times 346/1776$$

Where:
Q = streamflow of Way Sekampung DAM (catchment area of 346 km^2)
Q1776 = streamflow of Bendung Argoguruh with catchment area of 1,776 km^2. The catchment area is plotted in Table 1.

Table 1

Elevation, inundation, volume correlation

Elevation (m)	*Width of inundation (ha)*	*Volume of reservoir (jt m^3)*
130.00	767.54	111.87
129.00	743.81	104.31
128.00	722.28	96.98
127.00	700.65	89.87
126.00	677.94	82.97
125.00	653.72	76.31
124.00	502.25	70.53
123.00	476.80	65.64
122.00	437.06	61.07
121.00	417.38	56.80
120.00	400.68	52.71
119.00	385.78	48.77
118.00	371.62	44.99
117.00	357.57	41.34
116.00	341.80	37.85
115.00	325.66	34.51
114.00	310.75	31.33
113.00	296.30	28.29
112.00	280.71	25.41
111.00	266.21	22.67
110.00	251.38	20.08
109.00	218.32	17.73
108.00	205.37	15.62
107.00	193.24	13.62
106.00	181.60	11.75
105.00	169.39	9.99
104.00	151.58	8.39
103.00	137.61	6.94
102.00	121.18	5.65
101.00	107.02	4.51
100.00	92.05	3.51
99.00	78.38	2.66
98.00	62.46	1.96
97.00	50.21	1.39
96.00	41.99	0.93
95.00	26.02	0.59
94.00	16.25	0.38
93.00	11.15	0.24
92.00	8.52	0.15
91.00	7.39	0.07

Based on the analysis result of water balance, it can be concluded that the water supply does not satisfy the yearly demand. The Sekampung River has been the source of water supply, which is not supported by conservation efforts, and this can lead to dramatic consequences for human survival. If the conservation efforts are not appropriately managed, the flood in rainy season and the drought in dry season are certainly inevitable. The only solution which can be considered is the storing of a large volume of water (in rainy season) which flows in the river by building barrier and building artificial water reservoir such as catchment reservoir (long storage reservoir). In order to store the water in the planned storage infrastructure, in order to be used when it is demanded, the river should be closed along the stream with a dam until it reaches to a certain elevation so the streamflow cannot pass freely through to the downstream resulting in a large catchment area (Navrud & Ready 2002).

The estimation of potentially occurred sediment rate in the watershed can be measured with the equation of Weischmeier & Smith (1958) as follow:

$$S\text{-}pot = E\text{-}Akt \times SDR$$

Where: S-Pot = Potential Sediment (ton/year)
E-Akt = Actual Erosion in the watershed (ton/ha/year)
SDR = Sediment Delivery Ratio (%)

The estimation measurement of sediment rate is presented in Table 2.

Table 2

The measurement of potential sediment

Elevation (m)	*Slope (%)*	*Average slope (%)*	*Slope length (m)*	*Width (km^2)*	*Width (ha)*	*Hill slope*	*Erosion potential (ton/year)*	*Actual erosion (ton/ha)*	*SDR*	*Potential sediment (ton)*
>250	8-15	12.0	6.767	57.83	5.782	1.516	69.407.45	138.814.9	0.54	75.368.08
	45-65	50.0	13.826	214.81	21.481	525.29	89.310.368.7	178.620.7	0.55	98.122.43
	45-65	55.0	5.797	41.40	4.139	356.33	11.675.799.3	23.351.60	0.57	13.389.23
225-250	8-15	11.5	1.767	16.14	1.613	366.48	4.80.860.8	9.361.72	0.57	5.295.13
Total land erosion (km^2)				330.17						
Width of river (km^2)				0.000		Total sediment potential			(Ton/ha)	192.174.87
Width of watershed (km^2)				330.16		Total sediment potential			(m^3/ha/t)	3.53
Average erosion rate in the field				0.64	mm/t/h				M3/T/H)	116.469.62

Width of catchment area = 330.17 km^2
Monthly rainfall (R) = 151.21 mm
Manning's roughness coefficients (n) = 0.02 (flow of coarse surface)
Factor of Soil Tillage Index(CP) = 0.002 (mixed farms, field)
Index of soil erodbility = 0.38 (size of volcanic dust, clay and organics 30%, 20%, 5%)
Kinetic energy of raindrop = 3.166.8
Maximum rainfall intensity for 30 days = 0.66
Index of rain erosivity (EI130) = 20.83

The sediment delivery ratio is show in the Figure 5.

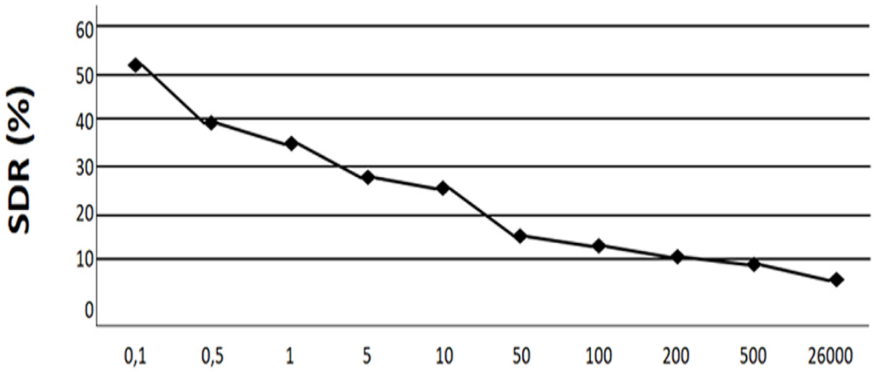

Figure 5. Sediment delivery ratio according to the Robinson (1979) method.

Capacity of sediment of dead storage. The total sediment potential is 116.469.62 m^3/year. The designed duration of the dam is estimated for 50 years, the volume of dead storage would be 50 x 116.469.62 m^3, which means a total of 5.823.480.90 m^3 sediment with an elevation of 102.134 m. The dead storage is marked by the elevation of sediment which possesses only the volume of sediment without water reservoir as seen on Figure 6 and as showed in Table 2.

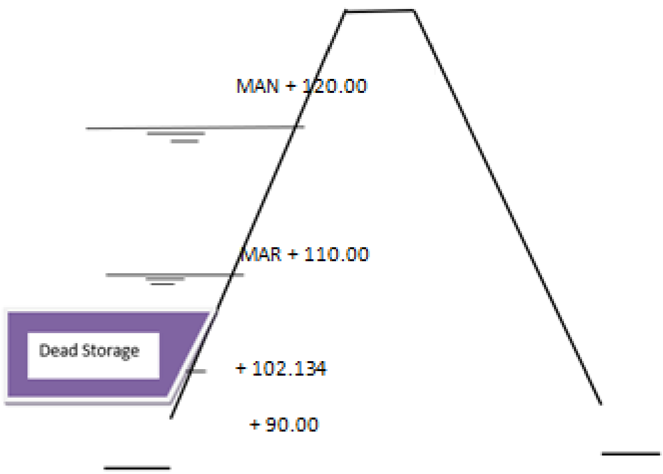

Figure 6. Scheme of catchment reservoir.

Results and Discussion. System requirements were obtained by identifying the needs of each stakeholders and relating them to the dam/reservoir development plan. Interviews were conducted with the Government as the planning and policy makers, with businessmen and with the civil society. The needs of each stakeholder from the system are presented in Table 3.

Table 3

System requirements matrix

Needs analysis	*Government*	*Society*	*Businessmen*
Check dam	✓✓✓	✓✓✓	✓✓
Socialization	✓✓	✓✓✓	✓✓
Catchment area	✓✓✓	✓✓✓	✓✓
Waste management	✓✓	✓✓✓	✓
Budget	✓✓✓	✓	✓
Illegal logging control	✓✓✓	✓✓✓	✓✓
Socialization	✓✓✓	✓✓	✓

✓ = Important
✓✓ = More Important
✓✓✓ = Most Important
Check dam - structure located in the middle of the river with the function to block the sediment (rocks and sands) entering the river flow.

Problem formulation. Based on the results obtained from the needs analysis, several problems were identified such as:

- Dam
  Dams mainly store, and drain water. This affects the availability of raw water, thus efforts are needed to maintain the environmental conditions, such as the forests around the dam.
- Reforestation
  Reforestation helps to maintain the conditions of the dam. It is therefore necessary to frequently monitor and control the areas around the dam.

System identification. There are four groups of variables that affect the systems' performances, namely: (1) The desired output - this was used to examine the success of the built model. The objective of the sustainable dam construction model was to increase the adequacy of raw water, the adequacy of irrigation water, and the fulfillment of green open space; (2) Controlled input - this was used to optimize the desired output. Dams and reforestation are inclusive in this variable; (3) Uncontrolled input - this greatly affected the performance of the model because it was difficult to control, and it became a major concern in policy elaboration. Rainfall and population were used as an assumption in this model; (4) Unwanted output, such as water crisis, food imports and high drought were not in line with the expectations. The relationship between the variables that affected the systems' performance is presented in Figure 7.

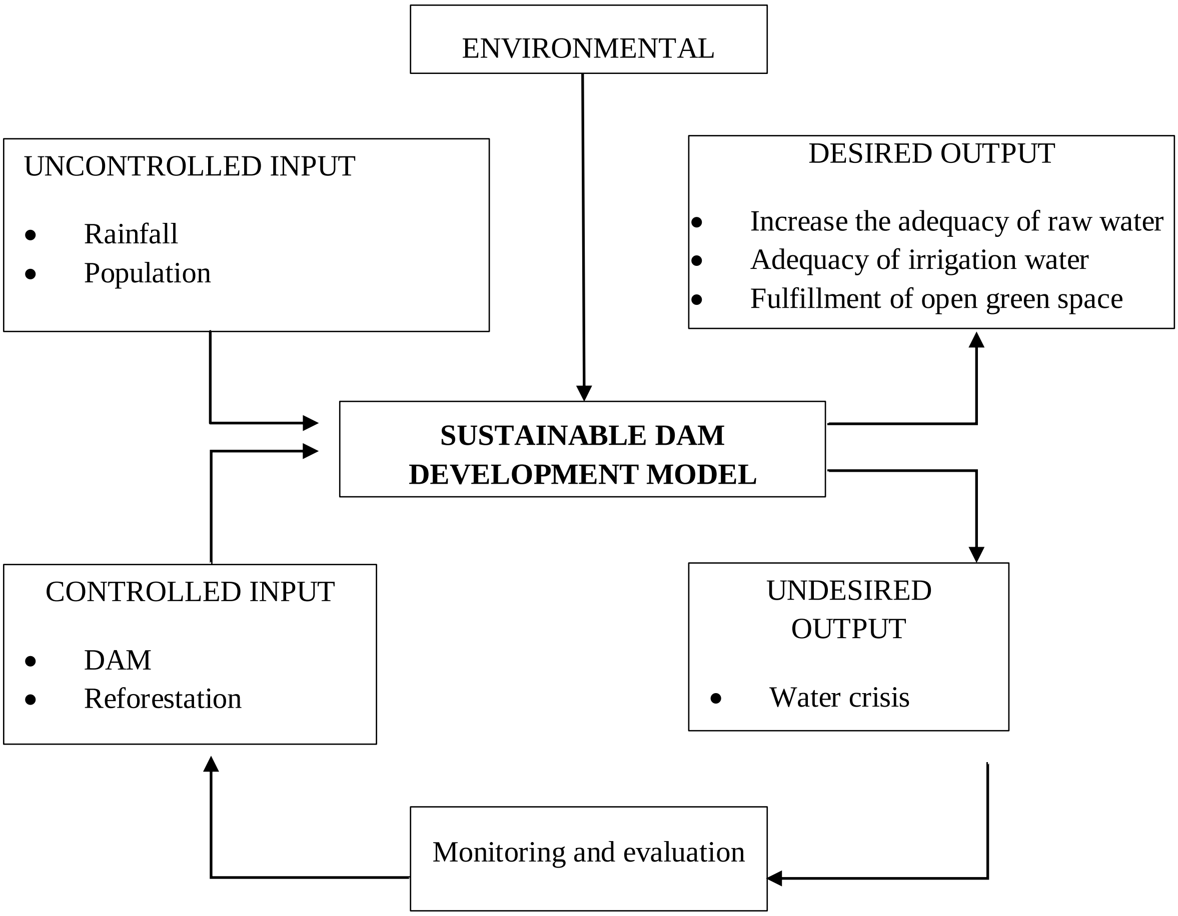

Figure 7. Variables which affect the system performance.

Causal Loop Diagram. The description of the Black Box on the variables that affected the performances of the system was outlined in the causal loop diagram. This helped to deduce the relationship between the variables in the system. This diagram was used as an interpreter for each of the variables that influenced the availability of water, which has a relationship or an influence on the existing system (Figure 8). In Figure 8, it can be deduced that water requirements were influenced by factors such as: population (BPS 2015), agricultural area and industrial area. An increase in these factors, leads to an increase in the need for water and alternatively a decrease in these factors, leads to a decreased water demand.

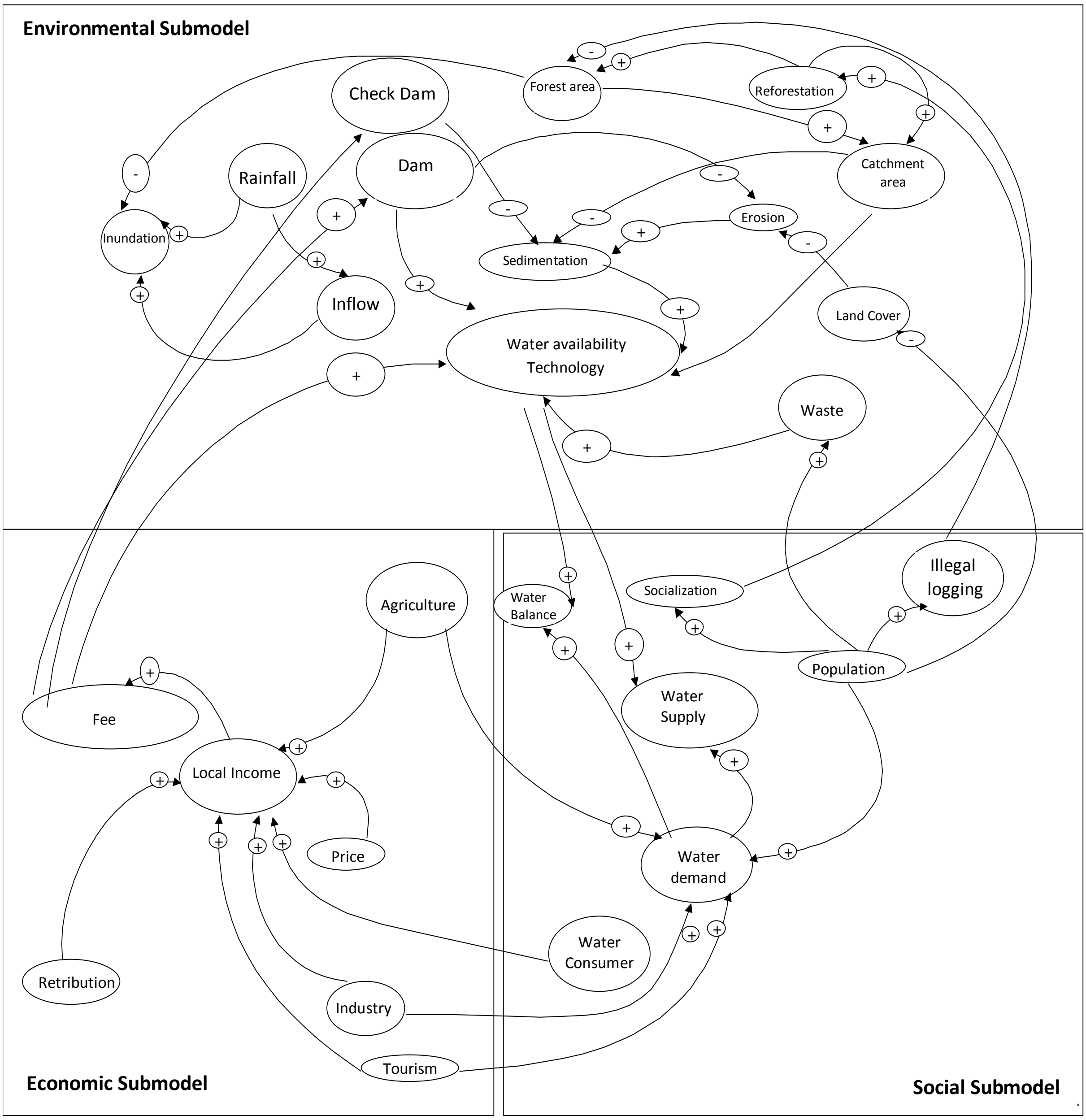

Figure 8. Causal Loop Diagram.

Simulation and modeling. The simulation and modeling sub models were divided into environmental, economic and social sub models. In the environmental sub models, the forest areas tend to affect the catchment areas and this automatically affects the water balance. Variables in the social sub model were mostly the population which was affected by death and birth rates and this affected the size of the settlement area in the environmental sub model (Loucks 2000). Sub-economic models were influenced by agricultural variables and this also affected the agricultural water needs. The relationship between the variables in the simulation and the modeling sub-models are s illustrated in the Stock Flow Diagram (Figure 9).

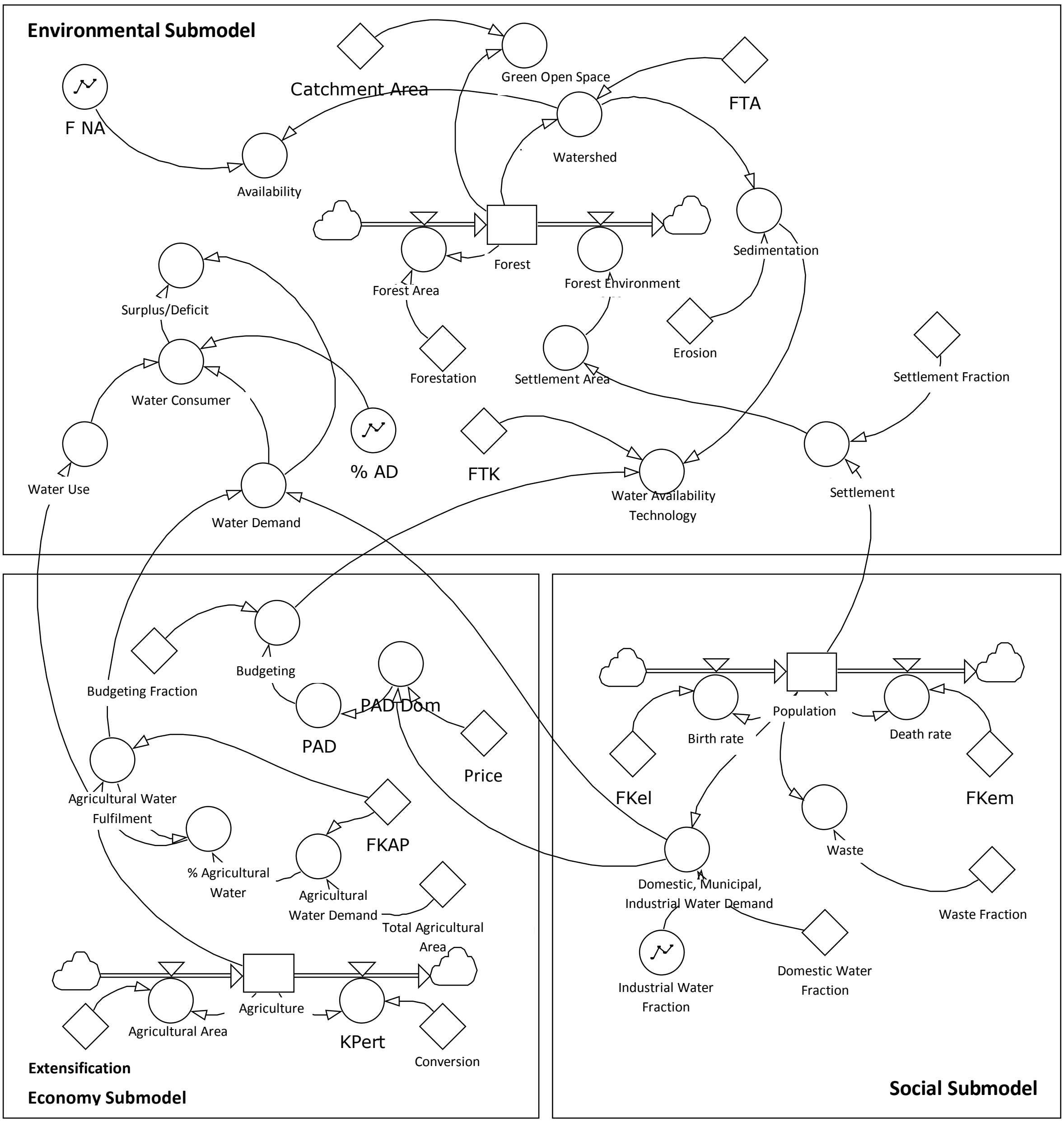

Figure 9. Stock Flow Diagram (FNA = Fraction Number Availability; FTA = Fraction Total Availability; %AD = Percentage of Availability Demand; FTK = Fraction Technology Conversion; PAD = Local Income in each district; FKAP = Fraction of Agriculture Water Demand; FKEM = Death rate Fraction of the population; FKEL = Birth rate Fraction of the population; KPert = Agriculture Conversion).

The correlation of the forest area, settlement area, agricultural area, and the green open space, can be seen in the Table 4.

Table 4

The correlation between each variable in the dynamic system

Year	*Forest area (Ha)*	*Settlement area (Ha)*	*Agricultural area (Ha)*	*Green open space (%)*
13	427.55	72,113.57	56,000.00	2.89
14	429.57	73,721.70	55,720.00	2.90
15	430.00	75,365.70	55,441.40	2.91
16	428.78	77,046.35	55,164.19	2.90
17	425.88	78,764.49	54,888.37	2.88
18	421.25	80,520.94	54,613.93	2.85
19	414.83	82,316.55	54,340.86	2.80
20	406.59	84,152.21	54,069.16	2.75
21	396.47	86,028.81	53,798.81	2.68
22	384.42	87,947.25	53,529.82	2.60
23	370.40	89,908.47	53,262.17	2.50
24	354.34	91,913.43	52,995.86	2.39
25	336.20	93,963.10	52,730.88	2.27
26	315.92	96,058.48	52,467.22	2.13
27	293.44	98,200.58	52,204.89	1.98
28	268.71	100,390.45	51,943.86	1.82
29	241.66	102,629.16	51,684.14	1.63
30	212.24	104,917.79	51,425.72	1.43

Forest area in 2013 covered 427.55 ha and there was a decrease for year 2030 with a covering an area of 212.24 ha. The catchment area decreased from 213.78 ha in 2013 to 106.12 ha for year 2030. The existing green space in 2013 was 2.89% and it was predicted to decrease to 1.43% in 2030 (Figure 10).

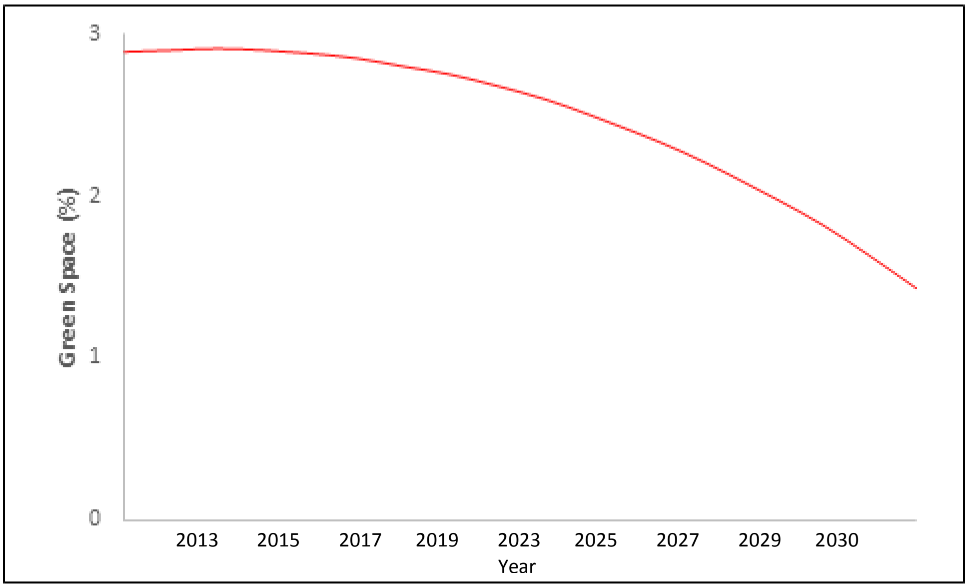

Figure 10. Extent of green space.

Agricultural areas from 2013 to 2030 show a decreasing tendency, while residential areas show an increasing tendency. The size of the agricultural area decreased from 56,000 ha in 2013 to 51,425 ha for year 2030, while the areas for settlement increased from 72,113 ha in 2013 to 104,917 ha in 2030 (Figure 11). This is because residential areas were increasing with respect to the increasing population.

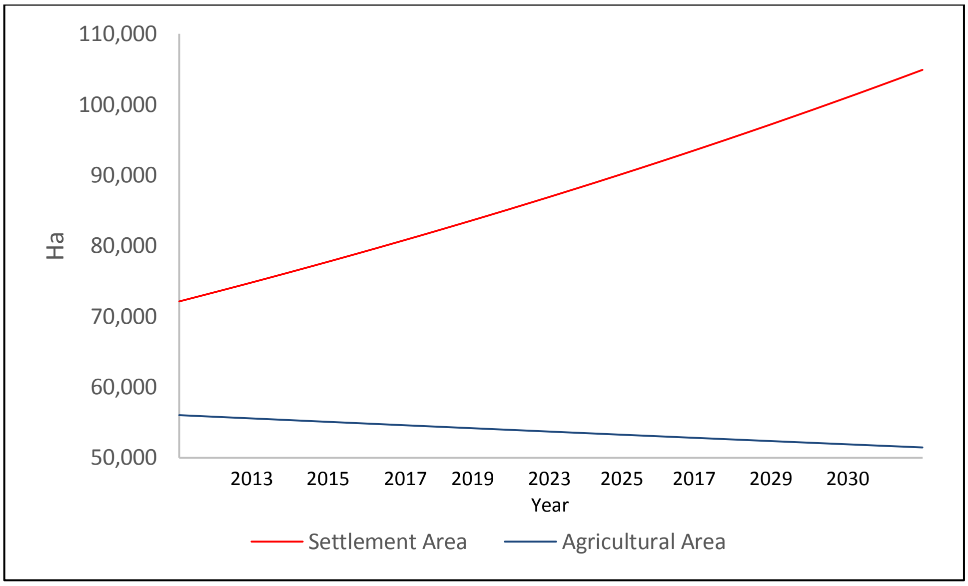

Figure 11. Settlement and agricultural areas evolution.

Water needs increased significantly from 4,436,680,039.99 m^3/year in 2013 to 4,812,015,149.31 m^3/year for year 2030 (Figure 12). This is in line with the significant increase in the size of the residential areas. The use of water also increased from 2,456,934,813.26 m^3/year to 2,499,359,679.69 m^3/year.

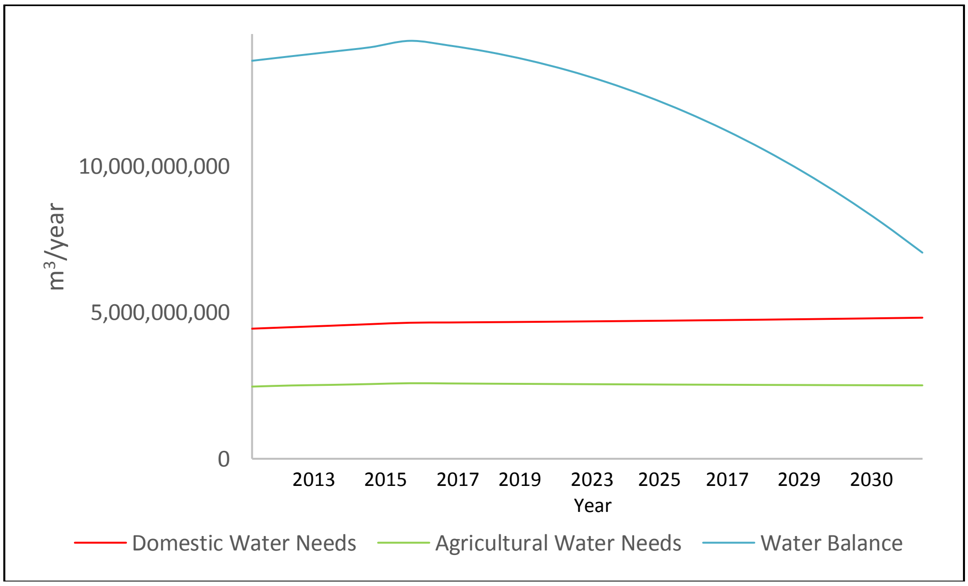

Figure 12. Domestic, agricultural water needs and water balance (m^3/year).

From the Figure 12 can be seen that water availability decreased from 13,592,806,416.00 m^3/year in 2013 to 7,035,613,484.38 m^3/year for year 2030. This was due to the need for water which continued to increase from 2013 to 2030, so the availability of water in 2030 experienced a deficit of 0.52% (Figure 13).

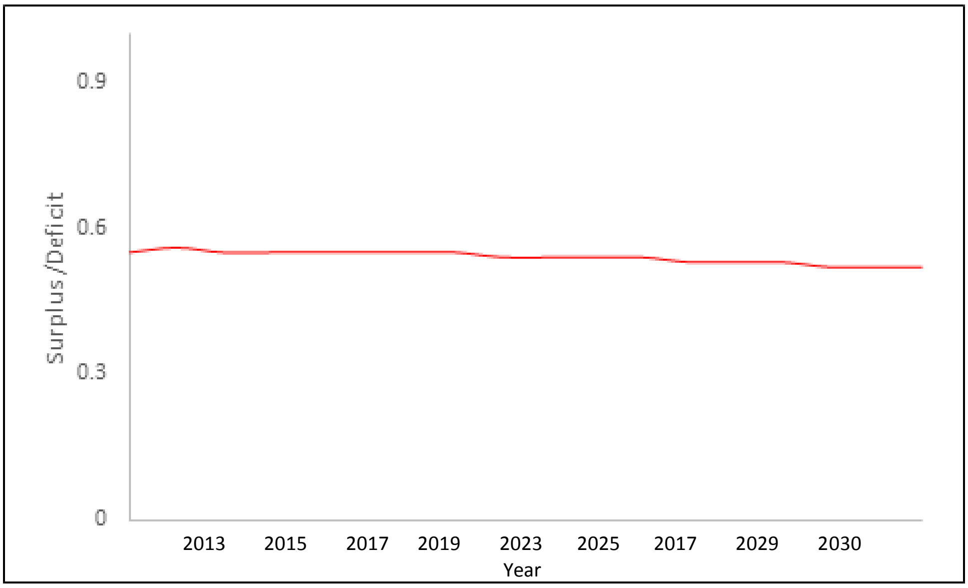

Figure 13. Water supply surplus/deficit chart.

The correlation of the domestic water needs, agricultural water needs, water balance, and surplus deficit in one model, can be seen in the Table 5.

Table 5

The interaction between each variable in one model

Year	*Domestic water needs (m^3/year)*	*Agricultural water needs (m^3/year)*	*Water balance (m^3/year)*	*Surplus/ Deficit*
13	4,436,680,039.99	2,456,934,813.26	13,592,806,416.00	0.55
14	4,487,710,731.41	2,494,995,636.39	13,748,090,813.61	0.56
15	4,537,769,453.27	2,515,802,913.67	13,900,037,867.29	0.55
16	4,590,448,326.65	2,543,538,369.03	14,055,174,352.48	0.55
17	4,639,426,724.15	2,571,970,858.65	14,274,915,735.64	0.55
18	4,648,375,540.45	2,564,047,177.64	14,114,806,728.19	0.55
19	4,657,996,467.35	2,556,507,317.17	13,894,853,467.80	0.55
20	4,668,302,130.16	2,549,352,687.36	13,613,440,058.51	0.55
21	4,679,305,447.55	2,542,584,774.32	13,268,913,163.05	0.54
22	4,691,019,638.01	2,536,205,140.94	12,859,581,160.85	0.54
23	4,703,458,226.52	2,530,215,427.68	12,383,713,287.22	0.54
24	4,716,635,051.31	2,524,617,353.40	11,839,538,753.42	0.54
25	4,730,564,270.76	2,519,412,716.23	11,225,245,846.87	0.53
26	4,745,260,370.51	2,514,603,394.41	10,538,981,011.47	0.53
27	4,760,738,170.70	2,510,191,347.17	9,778,847,907.21	0.53
28	4,777,012,833.37	2,506,178,615.67	8,942,906,448.88	0.52
29	4,794,099,870.01	2,502,567,323.92	8,029,171,823.27	0.52
30	4,812,015,149.31	2,499,359,679.69	7,035,613,484.38	0.52

The validation of water need variables, water use variables, and water availability variables, can be seen in the Table 6, Table 7, and Table 8, respectively.

Table 6

Validation of water needs variables

Year	Actual value	Simulation value
2013	4,436,380,495.24	4,436,680,039.99
2014	4,486,177,060.62	4,487,710,731.41
2015	4,536,532,572.17	4,537,769,453.27
2016	4,587,453,303.84	4,590,448,326.65
2017	4,638,945,600.00	4,639,426,724.15
Mean	4,537,097,806.37	4,538,407,055.09
AME	0.028856524	
Variance	3,054,578,944,904,480.00	3,125,440,663,658,730.00
AVE	2.319852262	

Table 7

Validation of water use variables

Year	Actual value	Simulation value
2013	2,457,953,843.39	2,456,934,813.26
2014	2,485,543,374.85	2,486,670,417.61
2015	2,513,442,587.57	2,515,802,913.67
2016	2,541,654,957.60	2,543,538,369.03
2017	2,570,184,000.00	2,571,970,858.65
Mean	2,513,755,752.68	2,514,983,474.44
AME	0.048840137	
Variance	937,651,010,254,078.00	997,465,947,600,566.00
AVE	6.379232432	

Table 8

Validation of water availability variables

Year	Actual value	Simulation value
2013	13,593,540,316.93	13.592.806.416,00
2014	13,746,122,274.18	13.748.090.813,61
2015	13,900,416,901.79	13.900.037.867,29
2016	14,056,443,423.79	14.055.174.352,48
2017	14,214,221,280.00	14.274.915.735,64
Mean	13,902,148,839.34	13.914.205.037,00
AME	0.086721828	
Variance	28,678,665,507,081,200.00	30,192,813,080,108,500.00
AVE	5.279700245	

AME validation value for variable water needs is 0.02, for water use is 0.04 and for water availability is 0.08. AVE validation value for variable water needs is 2.31, for water use is 6.37 and for water availability is 5.27. The simulation results show a good level of validation because the second value of the performance validation is below 10%.

Moderate scenario. The moderate scenario will be carried out through reforestation in 2020 with the 5% of additional green open space and the construction of dams in 2022 with an effectiveness of 50%. The results of moderate scenarios will be as presented in Figure 14 and Figure 15.

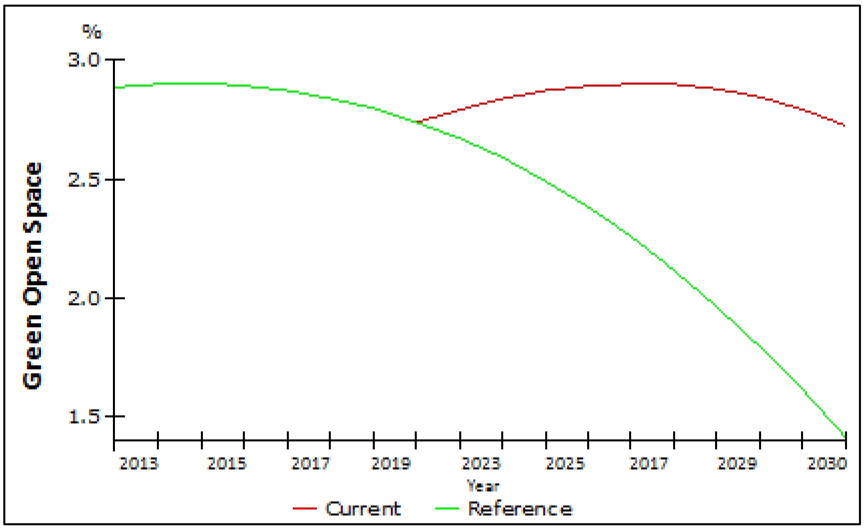

Figure 14. Graph of moderate availability of green open space.

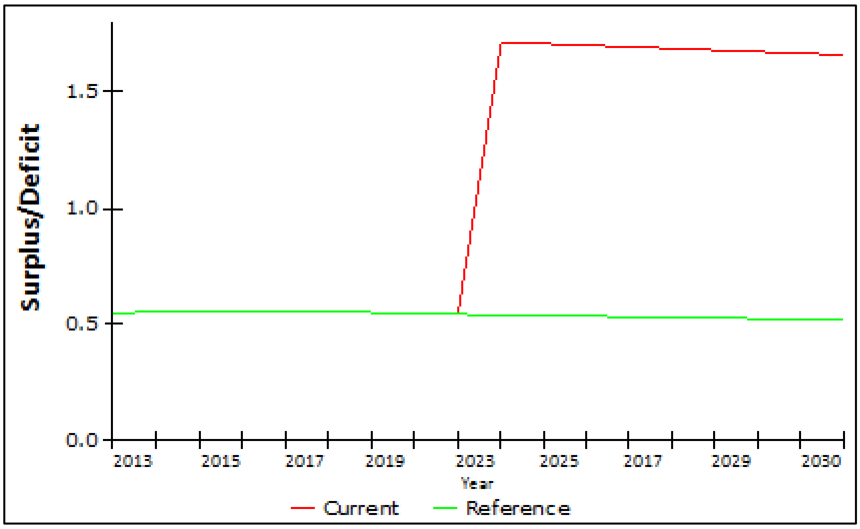

Figure 15. Graph of moderate water availability scenario.

Moderate scenarios will be carried out by means of reforestation activities in 2020 and dams will be usable as from 2022. In 2021, the availability of green open space will increase from 2.74% to 2.79% (Table 9). Nevertheless, without the scenarios the yield will be probably 2.67%. In moderate conditions, the availability of green open space in 2030 is estimated to reach 2.73%. In 2022, the dam can be used. Prior to the dam, the adequate availability of water has not been a challenge. Until 2030, the availability of water will still be 0.52. Further development in 2022 will upsurge the availability of water about 1.71. That means the availability of water will be in surplus. By 2030, water availability will be probably 1.66 (Table 10). This is essentially due to the state of the dam since it will be affected by sedimentation factors. Nonetheless, the supply will still be in a surplus (fulfilled).

Table 9

Percentage of the green open space (%)

Year	Current	Reference
13	2.89	2.89
14	2.90	2.90
15	2.90	2.90
16	2.89	2.89
17	2.87	2.87
18	2.84	2.84
19	2.80	2.80
20	2.74	2.74
21	2.79	2.67
22	2.84	2.59
23	2.87	2.49
24	2.89	2.38
25	2.90	2.26
26	2.90	2.12
27	2.88	1.97
28	2.85	1.80
29	2.79	1.62
30	2.73	1.42

Table 10

Surplus/deficit

Year	Current	Reference
13	0.55	0.55
14	0.56	0.56
15	0.55	0.55
16	0.55	0.55
17	0.55	0.55
18	0.55	0.55
19	0.55	0.55
20	0.55	0.55
21	0.54	0.54
22	1.71	0.54
23	1.70	0.54
24	1.70	0.54
25	1.69	0.53
26	1.68	0.53
27	1.68	0.53
28	1.67	0.52
29	1.66	0.52
30	1.66	0.52

Optimistic scenario. The optimistic scenario will be brought about by reforestation in 2020 with 10% of additional green space and the construction of dams in 2022 with an effectiveness of 100%. The results of moderate scenarios would be as presented in Figure 16 and 17.

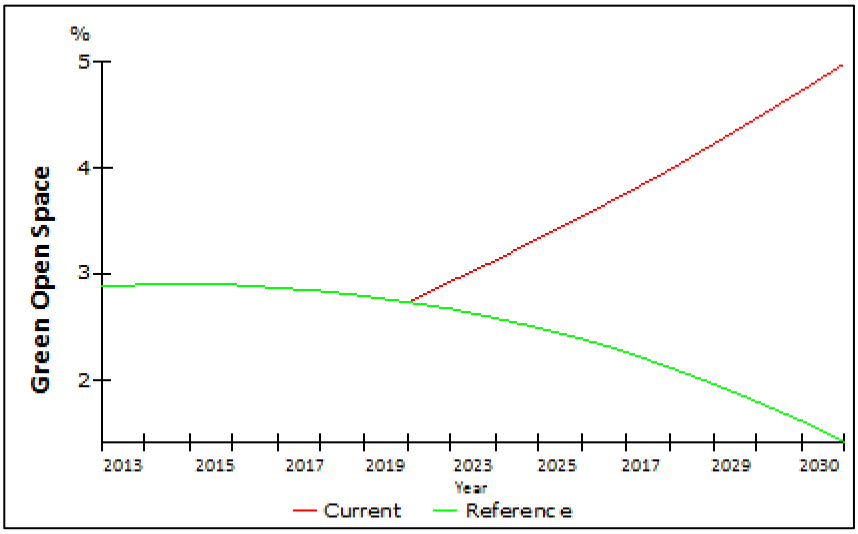

Figure 16. Moderate scenario for availability of green open space.

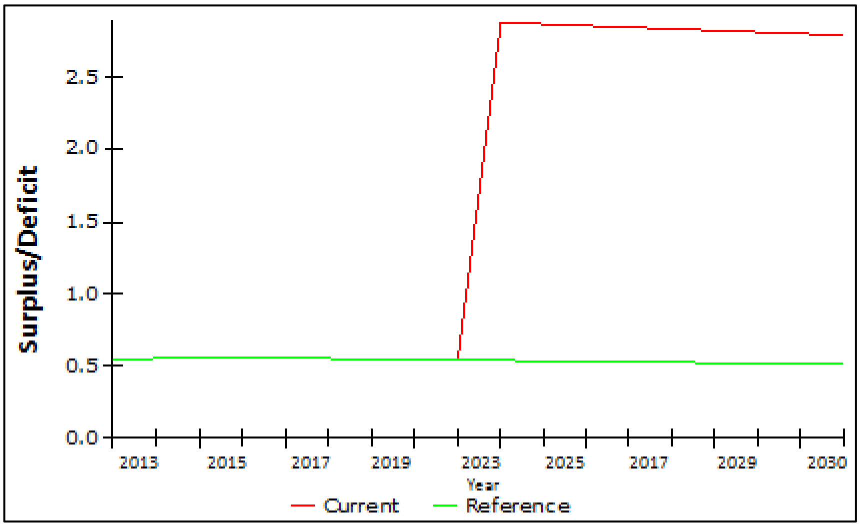

Figure 17. Moderate water availability scenario.

The optimistic scenario will be as a result of reforestation activities in 2020 and the dam will be usable from 2022. In 2021, the availability of green open space will increase from 2.74% to 2.93% (Table 11), and after the scenarios it will be 4.99%. In moderate conditions, the availability of green open space in 2030 will probably reach 2.73% and by 2022, the dam can be used. Prior to the existence of the dam water availability will be scanty untill 2030. It will be still 0.52, implying a deficit condition. With the development in moderate conditions in 2022, the availability of water will go to approximately 2.87, a surplus state. By 2030, the availability would be around 2.79 (Table 12). This condition is attributed to the effects of sedimentation to the dam. However, in 2030 the availability will still be in surplus (fulfilled).

Table 11

Percentage of the green open space (%)

Year	*Current*	*Reference*
13	2.89	2.89
14	2.90	2.90
15	2.90	2.90
16	2.89	2.89
17	2.87	2.87
18	2.84	2.84
19	2.80	2.80
20	2.74	2.74
21	2.93	2.67
22	3.13	2.59
23	3.33	2.49
24	3.54	2.38
25	3.76	2.26
26	3.99	2.12
27	4.23	1.97
28	4.47	1.80
29	4.72	1.62
30	4.99	1.42

Table 12

Surplus/deficit

Year	*Current*	*Reference*
13	0.55	0.55
14	0.56	0.56
15	0.55	0.55
16	0.55	0.55
17	0.55	0.55
18	0.55	0.55
19	0.55	0.55
20	0.55	0.55
21	0.54	0.54
22	2.87	0.54
23	2.87	0.54
24	2.86	0.54
25	2.85	0.53
26	2.84	0.53
27	2.83	0.53
28	2.82	0.52
29	2.81	0.52
30	2.79	0.52

Conclusions. The study made a number of deductions. Firstly, mitigation policies such as building sustainable dams like Way Sekampung dam needs implementation. Secondly, the management of water resources in the dam faces obstacles such as decrease in water absorption functions. These results were obtained from reduced vegetation in the catchment area along with lack of coordination and integration of water resources management between key stakeholders. The program needed in the utilization of sustainable water resources in the area include the construction of the Way Sekampung dam, reforestation and increased awareness in stakeholders (Government, business and industry, academics, communities and NGOs). Based on the results of the dynamic system simulation, water demand in 2013 was 4,436,680,040 m^3/year, while the supply was 13,592,806,416 m^3/year, with only 2,456,934,813 m^3/year utilized. In 2030, the availability of water would be in abundance though utilization will be still not optimal. In the same year the water demand will be probably 4,812,015,149 m^3/year and the availability being 7,035,613,484 m^3/year. Nevertheless, only 2,499,359,680 m^3 can be utilized. Moderate and optimistic scenarios will translate to surplus state. Each of the scenarios has a different water requirement, approximately 1.66 times the surplus of water in the moderate scenario and 4.99 times in the optimistic scenario.

The decrease of the supply of water resource is caused by the damage of the catchment area environment, resulting in the decrease of available soil water storage capacity. This degradation resulted because humans neglecting the environment such as forest logging, the groundwater pumping, the expansion of agricultural area, the expansion of residential areas also the issue of climate change leading to longer dry season. Presently, the status of the sustainable utility of water resource in Way Sekampung amounts 41.10 at the stage of less sustainability as shown at the index positioning between 25.00 until 49.99. In detail, the dimensions of economy, ecology and social require to meet the expected goals of the sustainability of dams development in Way Sekampung.

Suggestions. To fulfill the demand of water due to the scarcity of water resources can be done by simple technical and non-technical improvements. Technical ways in principal is to replace the function of trees root system which able to take up the rainwater in catchment area such as constructing water storage facility like dam in river flow, therefore the water can be stored to be used then in dry season. Therefore, by constructing the dam, the water flow can be managed according to the demands. Also, the researchers urge related parties to implement the policy and government programs in order to maintain the water infiltration which naturally becomes the water storage.

References

Arsyad S., 2010 Konservasi Tanah dan Air. IPB Press, Bogor, Indonesia.

Asdak C., Hidrologi dan Pengelolaan Daerah Aliran Sungai. Gadjah Mada University Press, Yogyakarta, Indonesia.

Budi S., 2008 Redesain Kebijakan Pembangunan Pulau Batam yang Berdaya Saing dan Berkelanjutan. Dissertation, Pertanian Bogor Institute, Bogor, Indonesia.

Eriyatno, 2003 Ilmu Sistem: Meningkatkan Mutu dan Efektivitas Manajemen. IPB Press, Bogor, Indonesia.

Fauzi A., 2014 Valuasi Ekonomi dan Penilaian Kerusakan Sumber Daya Alam dan Lingkungan. Pertanian Bogor Institute, Bogor, Indonesia.

Firmansyah I., 2015 Aplikasi Powersim Studio untuk Sistem Dinamik, Sistem Dinamik Center-Indonesia. Triwala Press, Bogor, Indonesia.

Firmansyah I., 2016 Model pengendalian konversi lahan sawah di dalam DAS Citarum. Disertasi. IPB Press, Bogor, Indonesia.

Navrud S., Ready R. C., 2002 Valuing cultural heritage – Applying environmental valuation techniques to historic buildings, monuments and artifacts. Edward Elgar Publishing, Inc. Massachusetts, USA.

Hardjomidjojo, 2007 Kajian Institusi Pengelolaan DAS dan Konservasi Tanah. Bogor (ID): K3SB Bogor, Indonesia.

Hartisari, 2007 Sistem Dinamik. Konsep Sistem dan Pemodelan untuk Industri dan Lingkungan. Pertanian Bogor Institute, SEAMEO BIOTROP, Bogor, Indonesia.

Hassan Pourfallah K., Reza M., Reza M., 2015 Water Resources Modelling Using System Dynamic in Vensim. A case study: risk analysis of sefid-rud dam reservoir intake decrease on downstream agricultural water demand. Journal of Water Resource and Hydraulic Engineering 4(3):251-256.

Indra K., Wiratman, Wiratman P. T., 2004 Laporan Akhir Review Detil Desain Waduk Jatigede di Kabupaten Sumedang.

Loucks D. P., 2000 Sustainable water resources management. Water International 25(1):2-10.

Manetsch T. J., Park G. L., 1977 System analysis and simulation with application to economic and social system. Part I., Third edition. Department of Electrical Engineering and System Science, Michigan State University, Michigan.
Marimin, 2004 Teknik dan Aplikasi Pengambilan Keputusan Kriteria Majemuk. Grasindo, Jakarta, Indonesia.
Muhammadi, Aminullah E., Soesilo B., 2001 Analisis Sistem Dinamis, Lingkungan Hidup, Sosial, Ekonomi, Manajemen. Jakarta (ID): UMJ Press, Indonesia.
Ridwan A. S., Yanuar M., Purwanto J., Asep S., Widiatmaka, 2014 Tank model to see the effect of land use changes on runoff, infiltration and groundwater in sub watershed of Konawe South East Sulawesi, Indonesia. Journal of Environment and Earth Science 4(14):107-117.
Rizal M., 2012 Model Perencanaan Pembangunan Bendungan yang Berkelanjutan. Institut Pertanian Bogor, Bogor, Indonesia.
Sterman J. D., 2004 Business dynamics: system thinking and modelling for a complex world. International Edition, Mc Graw Hill.
Wischmeier W. H., Smith D. D., 1965 Predicting rainfall-erosion losses from cropland east of the Rocky Mountains: a guide for selecting practices for soil and water conservation. USDA Agricultural Handbook No. 282.
Wischmeier W. H., Smith D. D., 1978 Predicting rainfall-erosion losses – a guide to conservation farming. USDA Agricultural Handbook No. 537.
*** [BPS] Badan Pusat Statistik, 2015 Lampung Dalam Angka. Badan Pusat Statistik Provinsi Lampung.

Received: 11 June 2018. Accepted: 15 February 2019. Published online: 04 March 2019.
Authors:
Mirza Nirwansyah, Bogor Agricultural University, Doctoral program of Environmental Studies and Natural Resources, Indonesia, 16680 Bogor, Gedung Sekolah Pascasarjana Lt.1 Kampus IPB Dramaga, e-mail: nirwans62@yahoo.com
Cecep Kusmana, Bogor Agricultural University, Indonesia, 16680 Bogor, Post Graduate School Building Lt.1 Kampus IPB Dramaga, e-mail: ckmangrove@gmail.com
Eriyatno, Bogor Agricultural University, Indonesia, 16680 Bogor, Post Graduate School Building Lt.1 Kampus IPB Dramaga, e-mail: eriyatno@yahoo.com
Mohamad Yanuar Jarwadi Purwanto, Bogor Agricultural University, Indonesia, 16680 Bogor, Post Graduate School Building Lt.1 Kampus IPB Dramaga, e-mail: yanuar.tta@gmail.com

How to cite this article:
Nirwansyah M., Kusmana C., Friyanto, Purwanto M. Y. J., 2019 A dynamic model for sustainable utilization of water resources in Way Sekampung, Lampung Province, Indonesia. AAB Bioflux 11(1):25-47.