A spatial economic model of the Ciliwung Watershed, in the western part of Java, Indonesia

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Abstract. This study aimed to map out the spatial economic structure of the Ciliwung Watershed and to analyze its spatial economic value. The research method used was survey method using a sampling method of Multi-Stage Sampling. The economic values were analyzed by prospective analysis, valuation of use value and non-use value, and dynamic system approach. While economic activities in the upstream and midstream areas of the Ciliwung Watershed are dominated by the primary sectors, economic activities in the downstream areas of the Ciliwung Watershed are dominated by the secondary sectors. The analysis results showed that the economic value of the upstream area of the Ciliwung Watershed was 17,467.61 million US$, of the midstream area of the Ciliwung Watershed 29,227.39 million US$ and of the downstream area of the Ciliwung Watershed 41,720.43 million US$. The per capita income of the upstream area of the Ciliwung Watershed was 0.00169 $year^{-1}$ million US$, and it would increase until 113% in the next 30 years; of the midstream area of the Ciliwung Watershed was 0.00154 $year^{-1}$ million US$ and it would increase until 105% in the next 30 years; and of downstream area of the Ciliwung Watershed was 0.01382 $year^{-1}$ million US$ and it would increase until 104% in the next 30 years. Integrated management is intended as an action that affects all dimensions that have important attributes for the sustainability of watershed management.

Key Words: connectivity, economic value, per capita income, valuation,

Introduction. The shift in the people's economic activities from the agricultural sector to the sectors of industry, trade and services has occurred significantly across the Ciliwung Watershed. Several studies have reported that the people's economic activities around the watershed resulted in land conversion and watershed degradation (Brouwer & Hofkes 2008). The high rate of land conversion has caused various problems (Mujio et al 2016).

According to Sadelie et al (2011), the land conversion to support local economic development is one of the indicators of planned deforestation, while unplanned deforestation is due to drought, plant age and population pressure in their attempt to meet their needs. Land commercialization around the Ciliwung Watershed is increasingly widespread, making many local farmers tempted to sell some or all of their land. As a result, the size of the land that the local farmers can use for farming activities keeps decreasing (Ruspendi et al 2013).

The community awareness of maintaining the Ciliwung Watershed ecosystem, especially in the upstream area, which is still far from expectation, has become a crucial issue. The awareness may rise because of two factors: internal and external. Internally, it is increasingly difficult to find people around the upstream area of the Ciliwung Watershed who have their own initiative to maintain the area as a strategic area for water catchment. This is mainly caused by the fast conversion rate of agricultural land and rice fields to physical buildings.

Another social issue that is equally important is the ever-increasing industrialization and household waste that continues to pollute the river. In addition, the increase in livestock raising activities along the Ciliwung Watershed also contributes to the river contamination. The land conversion that continues to occur for residential and industrial development along the upstream and downstream areas of the Ciliwung

Watershed has left no longer strategic areas but residential and business areas. This resulted in flooding in the downstream area and the decline in ecological and economic functions of the Jakarta bay waters (Ali et al 2016).

The decline of ecological and economic functions of the downstream area of the Ciliwung Watershed is contradictory with the ever-increasing population demand for life support facilities. The downstream area of the Ciliwung Watershed as a strategic area is being increasingly converted into business and residential area (Triuri & Marwasta 2012). As the site of the capital city and central government, the downstream area of the Ciliwung Watershed also accommodates the accumulative effects of the other parts' ignorant behavior in form of pollution and flooding (Ali et al 2016).

The fact that the upstream, midstream and downstream areas form an ecosystem, this requires the resource management to be integrated and holistic. The resource management is conducted through an ecosystem approach that is implemented based on the principle of one integrated watershed (Velazquez et al 2008). The downstream development which is imbalanced with the development in the upstream area will result in the low rate of welfare in the upstream area. On the contrary, the development that is only conducted in the upstream area will threaten the sustainability of the regional development in the downstream area.

The watershed management separation of upstream and downstream areas causes various problems. The above conditions show that the watershed management has not integrated and coordinated the upstream, midstream and downstream areas ecologically, socially and economically (Kusumastanto 2006; Amrullah et al 2015). Changes in one part of the watershed will affect the other part; in other words, the changes will bring about on-site effects as well as off-site effects (Volk et al 2008).

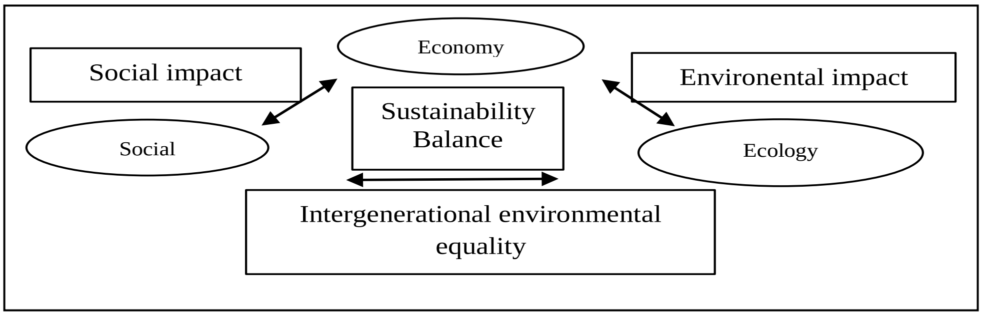


Figure 1. Connectivity of economic, social and environmental factors on sustainability balance (Munasinghe 1993; Kusumastanto 2006).

Therefore, the management of upstream-river basin resources requires to be integrated (integrated resource management) environmentally socially and economically as sub-systems to accommodate all interests (Widhiasari 2008). The multi-sectorial approach is a balancer in the sustainable use of the Ciliwung River basin resources.

Material and Method

Description of the study sites. The study was carried out in the western part of Java, Indonesia, covering areas as Bogor Regency, Bogor City, Depok City, South Jakarta, East Jakarta, Central Jakarta, West Jakarta and North Jakarta. The Ciliwung Watershed covers an area of 54,033.33 ha.

Method of data collection. The population considered in the present study includes stakeholders related to sub-sectors as food crop, forestry, plantation, animal husbandry, fishery and building construction in the Ciliwung Watershed. The sampling method used was Multi-Stage Sampling method, which uses various random sampling methods together efficiently and effectively (Malhotra 1993; Gay & Diehl 1992).

Spatial analysis of the Ciliwung Watershed. The calculation of the economic value of the Ciliwung Watershed used use value and non-use value. The use value approach used the value-added production approach, that is, the gross regional domestic product (GRDP). The value of GRDP is obtained from the increase in production subtracted by the production cost for each economic sector. Meanwhile, the calculation of non-use value which is the existing value the Ciliwung Watershed used Contingent Valuation Method approach by calculating the value of willingness to pay (WTP) which is predicted by Multiple Regression.

WTP per individual part can be directly obtained from the calculation of the average value using the following formula (FAO 2000):

$$\mathrm{MWTP} = \frac{1}{n}\sum_{i=1}^{n} \mathrm{WTP}_i$$

Where MWTP is average respondent's ability to pay for the improvement cost to each part of the Ciliwung Watershed (upstream, midstream and downstream); WTP_i is the ability of the i^{th} respondent to pay for the improvement cost to each part of the Ciliwung Watershed (upstream, midstream and downstream) and n is number of samples.

WTP per spatial part of the Ciliwung Watershed is calculated using the following formula.

$$WTP = WTP_i \times P_i$$

Where WTP is WTP per spatial part of the Ciliwung Watershed (upstream, midstream and downstream); WTP_i is WTP average per spatial part and P_i is total population in year t per spatial part.

Economic value of resources is calculated using the following formula.

$$EV = WTP + GRDP$$

Where EV is Economic Value per spatial part of the Ciliwung Watershed (upstream, midstream and downstream); WTP is WTP of the Ciliwung Watershed (upstream, midstream and downstream) and GRDP = GRDP in year t per spatial part of the Ciliwung Watershed (upstream, midstream and downstream)

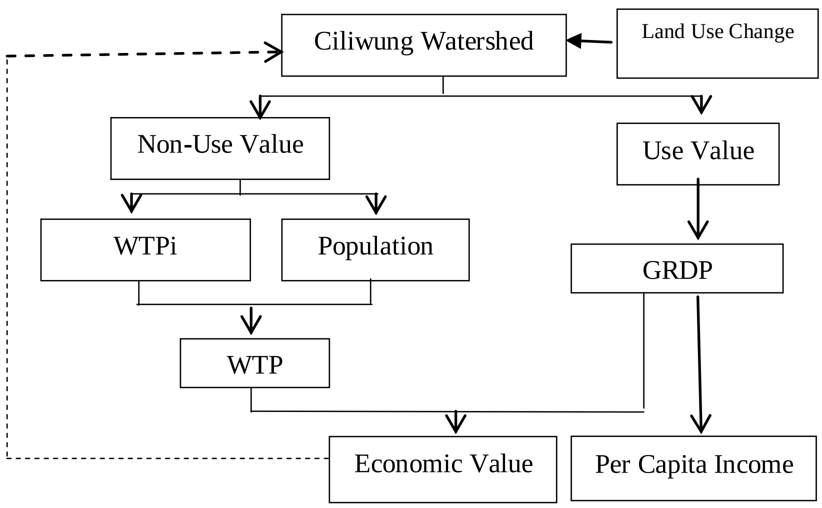


Figure 2. The economic spatial model of the Ciliwung Watershed.

Per capita income is counted using the following formula:

$$PI = GRDP/Population$$

Where PI is per capita income per spatial of the Ciliwung Watershed (Upstream, Midstream and Downstream); GRDP is GRDP in year t per spatial of the Ciliwung Watershed (Upstream, Midstream and Downstream) and Population is population in year t per spatial of the Ciliwung Watershed (Upstream, Midstream and Downstream). Spatial is data that has a picture of the region contained in the surface of the earth which is represented in the form of a map. In this case, spatial of the Ciliwung watershed is the administrative boundary based on the toposquence of the watershed is upstream, midstream and downstream.

Dynamic system modeling of spatial analysis. A spatial economic model approach is needed to understand the overall management of the economic aspects of the resources. Spatial economic modeling is done to see the interaction of ecological, social and economic variables with one another in a system. According to Volk et al (2008), the change of one part of the watershed not only affects the part itself (on-site effect) but also the other parts (off-site effect).

The Ciliwung Watershed management scenario is based on key factors in the prospective analysis. The strategic objective to be achieved in the future is the sustainable management of the Ciliwung Watershed (Gassman 2008). Based on the key factors, it will be made the description of various states that may occur in the future. The key factors which influencing the management of the Ciliwung Watershed are predicted to make the Ciliwung Watershed better, stagnant, or worse than the present condition.

From the selected variables, the stakeholders' representatives will determine better conditions for those variables for the next 30 years (according to the time dimension of the analysis). The variables are combined to get a desired scenario of the economic management model of the Ciliwung Watershed as can be seen in Table 1.

Table 1

Management scenario of spatial economic model of the Ciliwung Watershed

Input	*Scenario of dynamic model*		
	I	*Existing*	*II*
Forest (%)	15	20	25
Population growth (%)			
Upstream	2.5	2.1	1.6
Midstream	2.5	2.3	1.8
Downstream	1.4	0.97	0.4
Output (in next 30 years)			
Economic value	+	++	+++
Per capita income	+	++	+++

The management of the spatial economic model of the Ciliwung Watershed in this study used a dynamic system model approach. Dynamic system model is an abstraction of an existing object capable of predicting future possibilities based on time pattern. The modeling in this study used the existing scenario, namely scenario I and II. The software used to formulate and analyze the model built in the research was I-Think version 6.0.1.

The design of the dynamic model was based on the attribute values and their constituent dimensions (Harou et al 2009). Attribute values were derived from scientific estimation methods. The accuracy of parameter estimation depends on the availability of data as well as the analytical methods used. The attribute values for the ecological, economic and social aspects used to build and analyze the management of the spatial economic models of the Ciliwung Watershed can be seen based on their causal relationship.

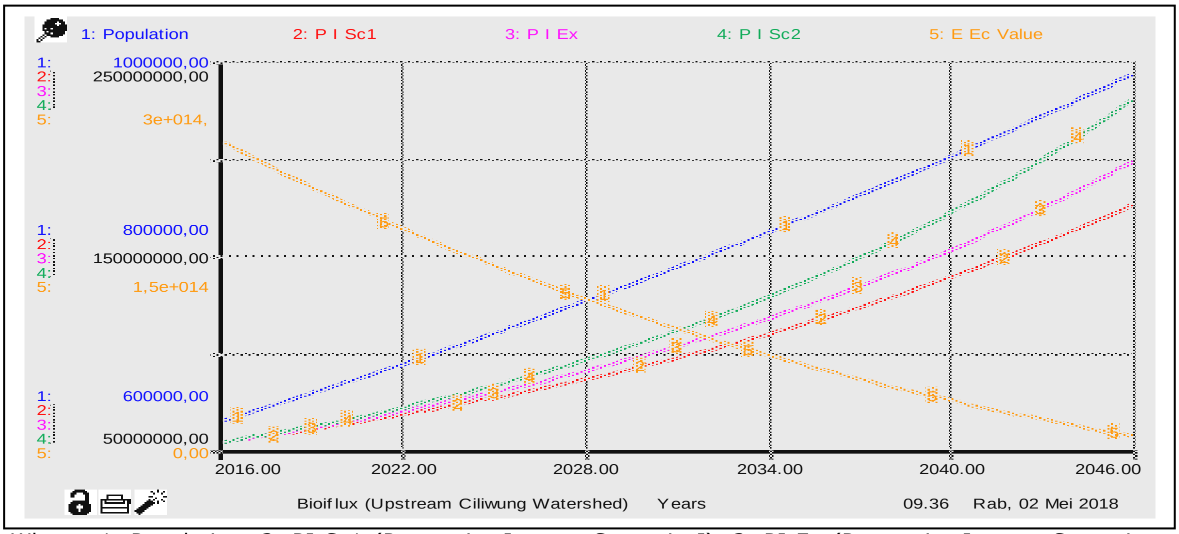
Results. The results of the analysis in this study are basically intended to see the economic spatial model of the Ciliwung Watershed as a result of changes in attribute values in the environmental, social and economic sub-systems in each spatial part of the Ciliwung watershed. The value of the initial attribute becomes an important aspect to see how much changes the various outputs attributes after the dynamic analysis.

$$WTP_{uppstream} = 8{,}048{,}642 + 16{,}910{,}500\ Income - 231{,}128\ Education - 69{,}831\ Age$$
$$WTP_{midstream} = 14{,}128.4 + 11{,}566{,}200\ Income - 342{,}817\ Education - 176{,}984\ Age$$
$$WTP_{downstream} = 6{,}199{,}099 - 2{,}778{,}520\ Income + 529{,}937\ Education - 28{,}537\ Age$$

Based on regression analysis, it is known that the per capita income variable had a positive effect on the upstream and midstream WTPs, but it had a negative effect on the downstream WTP. Education had a negative effect on the upstream and midstream WTPs, but it had a positive effect on the downstream WTP. Age has a negative effect on the three parts of the Ciliwung Watershed (Aini et al 2018).

The implications of scenarios or simulations performed using dynamic analysis showed various interrelated management changes. Multi-stakeholder roles such as government, community, and private sector and NGOs contribute to the spatial management of the Ciliwung Watershed simultaneously in capture fisheries resources in Jakarta Bay. Integrated management is intended as an action that affects all dimensions that have important attributes for the sustainability of watershed management (Kusumastanto 2007).

The economic value of the upstream area of the Ciliwung Watershed indicated the relationship between the sub-systems socially, economically and environmentally. The simulation result showed that the economic value of the upstream area of the Ciliwung Watershed in scenario I, existing scenario and scenario II decreased in the next 30 years. The economic value of the upstream part of the Ciliwung Watershed in the year of study was 17,467.61 million US$, which is predicted to decreasing in the next 30 years. The decline in the economic value of the upstream area of the Ciliwung Watershed in the next 30 years will be the lowest in scenario II amounting to 7,576.99 million US$, followed by in existing scenario 7,577.58 million US$ and scenario I 7,578.96 million US$ (Figure 3).



Where: 1. Population, 2. PI Sc1 (Per capita Income Scenario I), 3. PI Ex (Per capita Income Scenario Existing), 4. PI Sc2 (Per capita Income Scenario II), E Ec Value (Economy Value).

Figure 3. The economic value and per capita income of the upstream area of the Ciliwung Watershed.

The difference in economic values in the three simulations is relatively small, that is, 0.0051% on average. This means that the economic value of the upstream are of the Ciliwung Watershed is not significantly influenced by the population growth rate in the range of 2.5% (scenario I), 2.1% (existing scenario) and 1.6% (scenario II).

The simulation results of economic value of the upstream area of the Ciliwung Watershed in the next 30 years will decrease by 57% on average of the three scenarios. Compared to the economic value of the midstream and downstream areas of the Ciliwung Watershed, the percentage decline of the economic value of the upstream area of the Ciliwung Watershed will be the lowest. This is due to the pollution costs of the Ciliwung Watershed which are subtracted from the cost of liquid waste processing and pollution loads (Trofisa 2011). The pollution load of the upstream area of the Ciliwung Watershed was lower than that in the midstream and downstream areas of the Ciliwung Watershed, namely 3,457.62 m^3 sec^{-1}.

The simulation results showed that the per capita income increased along with the decrease in the population growth in the upstream area of the Ciliwung Watershed. In contrast, the per capita income of the population in the upstream area of the Ciliwung Watershed decreased in line with the increase of the population growth. This means that the per capita income was inversely proportional with the population growth rate.

The per capita income in the upstream area of the Ciliwung Watershed was supported by the tourism development in the Puncak region, a famous tourist destination in West Java. Since the upstream area of the Ciliwung Watershed is an ecological area which is suitable for ecotourism, the carrying capacity should be maintained or even enhanced. Maintaining or increasing the carrying capacity of the region means preserving the existence. The existing area can provide products and services continuously in the form of beautiful scenery, low temperatures, and attractive natural landscapes and in the form of potential for natural ecotourism typically of the region.

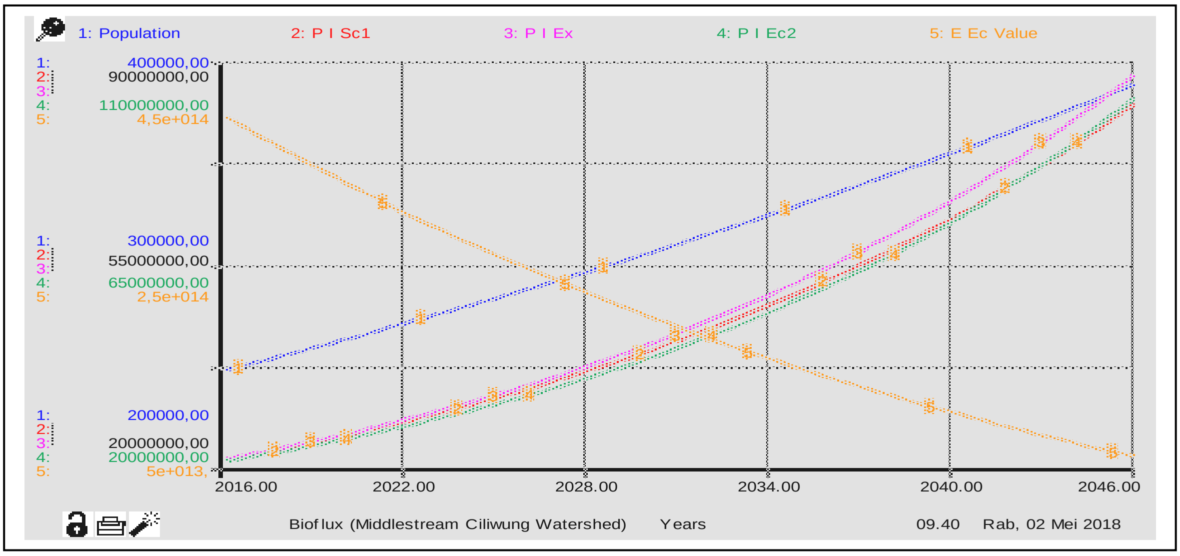
Changes in land use of the upstream area of the Ciliwung Watershed such as catchment area can damage the natural tourism activities. Therefore, maintaining the ecological aspects of the upstream area of the Ciliwung Watershed can increase the environmental capacity of the development of ecotourism activities that ultimately can increase the per capita income of the community. Pramono et al (2016) explains that per capita income is often used as one of the welfare indicators.

Some of the parties involved in the development of tourism services include the Department of Tourism, the Office of Agriculture and Forestry, the Department of Public Works, Bapeda, and local government, especially in the subdisticts of Ciawi, Megamendung and Cisarua. Sub-district authorities can play a role in building public perceptions and attitudes toward tourism business actors and tourism lovers in order to create a safe and conducive atmosphere by local communities (Suwarno et al 2011).

The simulation result of the interconnection among environmental sub-system, social sub-system and economic sub-system in the midstream area of the Ciliwung Watershed for the next 30 years showed different results. The income per capita of the population in the midstream area of the Ciliwung Watershed increased from the year of study, whereas the variable that decreased from the beginning of the year of research was the economic value (Figure 4).

The determinants of resource sustainability of the midstream area of the Ciliwung Watershed were not much different from the upstream area of the Ciliwung Watershed, i.e. land use change, biophysical quality of the midstream area of the Ciliwung Watershed, economic growth and population growth. These determinants had an impact on the environmental, social, and economic conditions of the midstream area of the Ciliwung Watershed. Based on research analysis, the output of the sustainability of the midstream area of the Ciliwung Watershed management from multi stakeholders include (1) changes of the midstream area of the Ciliwung Watershed cover to settlement and (2) increase of population income.

The economic value of the midstream area of the Ciliwung Watershed in the scenario I, existing scenario and scenario II will decrease in the next 30 years. The economic value of the midstream area of the Ciliwung Watershed in the year of study was 29,227.39 million US$ and would decrease in the next 30 years. The decline in economic value in the midstream area of the Ciliwung Watershed was the lowest for the next 30 years, which is, 4,504.65 million US$, followed by Existing Scenario 4,504.68 million US$ and Scenario I 4,504.67 million US$. The difference of economic values in the three simulations was relatively small in percentage, which is 0.00021% on average. This means that the economic value of the midstream area of the Ciliwung Watershed was not significantly influenced by the population growth in the range of 2.5% (Scenario I), 2.3% (Existing Scenario) and 1.8% (Scenario II).



Where: 1. Population; 2. PI Sc1 (Per capita Income of Scenario I); 3. PI Ex (Per capita Income of Scenario Existing), 4. PI Sc2 (Per capita Income of Scenario II), E Ec Value (Economic Value).

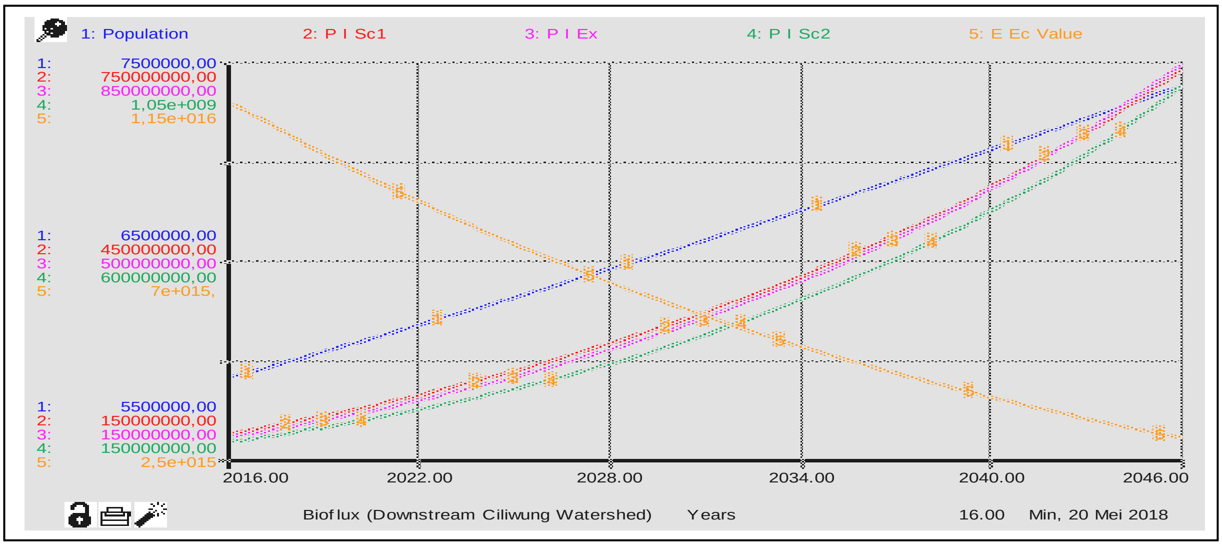
Figure 4. The economic value and per capita income of the midstream area of the Ciliwung Watershed.

The simulation results showed that per capita income increased along with the decrease in population growth in the midstream area of the Ciliwung Watershed. This means that per capita income is inversely proportional to the population growth rate. Pramono et al (2016) explains that per capita income is often used as one of the welfare indicators. Per capita income is the income earned by every resident in an area at a certain time.

The simulation variables for the next 30 years of the downstream area of the Ciliwung Watershed management showed different results. The population income per capita in the downstream area of the Ciliwung Watershed increased from year of study whereas the economic value variable decreased (Figure 5).

Determinants of the sustainability of the downstream area of the Ciliwung Watershed resources are land use change, biophysical quality accumulation from the upstream and midstream areas of the Ciliwung Watershed, economic growth and population growth in the downstream area. These determinants have an impact on the environmental, social, and economic conditions of the downstream area of the Ciliwung Watersheds.

The economic value of the downstream area of the Ciliwung Watershed showed sub-system interrelationship socially, economically and environmentally. The simulation results showed that the economic values of the downstream area of the Ciliwung Watershed in scenario I, existing scenario and scenario II would decrease in the next 30 years. The economic value of the downstream area of the Ciliwung Watershed in the year of research was 41,720.43 million US$ and would decrease within the next 30 years into the future. The decline in economic value in Scenario II was the lowest in the upstream area of the Ciliwung Watershed in the next 30 years, namely 218,785.94 million US$, followed by the Existing Scenario 167,336.46 million US$ and Scenario I 218,786.97 million US$. The difference in economic value in the three simulations was relatively small in percentage, namely, 0.00023% in average. This means that the economic value of the downstream area of the Ciliwung Watershed was not significantly influenced by the population growth rate in the range of 1.4% (scenario I), 0.97% (existing scenario) and 0.4% (scenario II).



Where: 1. Population, 2. PI Sc1 (Per capita Income Scenario I), 3. PI Ex (Per capita Income Scenario Existing), 4. PI Sc2 (Per capita Income Scenario II), E Ec Value (Economy Value).

Figure 5. The economic value and per capita income of the downstream area of the Ciliwung Watershed.

The simulation results of the economic value of the downstream area of the Ciliwung Watershed in the next 30 years used a dynamic system in the three scenarios decreased 72% in average, compared to the decline in the economic value in the upstream, midstream and downstream Ciliwung areas of the watershed. The percentage decrease in the economic value of the downstream area of the Ciliwung Watershed was higher than that of the upstream and midstream due to pollution accumulation, namely 20,674.66 m^3 sec^{-1}.

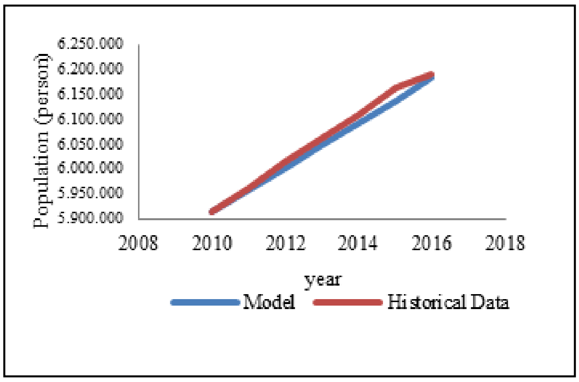
The population income per capita variable in the downstream area of the Ciliwung Watershed indicated the relationship between social sub-system and economic sub-system. The simulation results showed that in scenario I, existing scenario and scenario II, the income per capita of the population would increase in the next 30 years. The income per capita of the downstream area of the Ciliwung Watershed in the study year was 0.01 million US$. The highest increase of per capita income for the next 30 years would occur in scenario II, namely 0.03 million US$ to 0.071 million US$, an increase of 137%, while the existing scenario was 0.03 million US$ to 0.061 US$, an increase of 104% and scenario was I 0.02 million US$ to 0.036 US$, an increase of 79%.

Per capita income in the downstream area of the Ciliwung Watershed was higher compared to that of the midstream and upstream areas of the Ciliwung Watershed. Although per capita income variable is often used as a welfare indicator, it does not means that the number of the poverty-stricken people decreases in the downstream area of the Ciliwung Watershed. According to Pramono et al (2016), the number of the impoverished people in the downstream area of the Ciliwung Watershed fluctuates and tends to increase. Some of the causes of the condition include (1) the migration of the indigent people from one region to another to pursue a better living condition, (2) an increase in urban poverty, and (3) an increase in the composition of the needy category out of the total population.

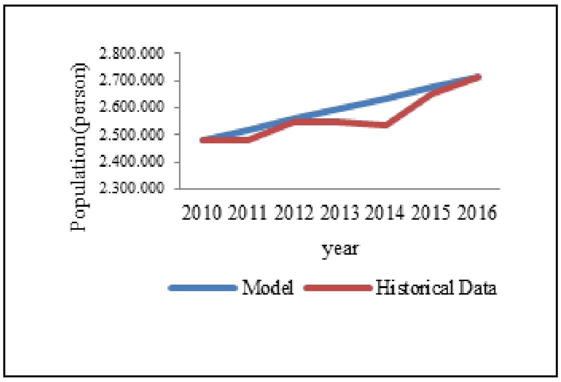
Model behavior validation. Model behavioral validation is performed to test the predictive behavior of models in the future. Validation is the final step in examining the model to find out whether the model output corresponds to the real system, taking into account internal consistency, correspondence, and representation. Prediction test is done by observing a trend of the model over variable changes. Model behavior validation on variables can be said to be valid if it has similar model resemblance.

Model behavioral validation is made to determine the level of output model compatibility with output from system performance. The result of validation is determined mathematically with RMSPEA (root mean square percent error approximation). RMSPEA shows the compatibility between the model output (ym) and the actual system output (ys), both of which form the limits to growth pattern. The RMSPEA criteria value can be statistically tolerable if it is less than 10%.

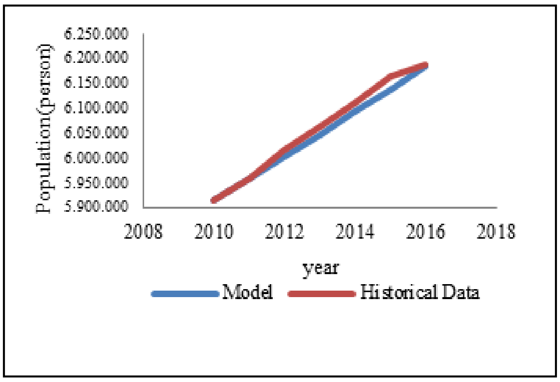
The validation of spatial model behavior of the Ciliwung Watershed could be said to be valid, because it was close to the original condition. The RMSPEA values tested on the population variables of the upstream, midstream, and downstream areas of the Ciliwung Watershed were 4.06%, 9.12% and 2.46% respectively (Figure 6).



a. Upstream



b. Midstream



c. Downstream

Figure 6. Population validation of the Ciliwung Watershed.

Conclusions. While the economic activities in the upstream and midstream area of the Ciliwung Watershed were dominated by the primary sector such as agriculture and mining, the economic activities in the downstream area of the Ciliwung Watershed were dominated by the secondary sector such as manufacturing, electricity, gas, water and construction industries. The economic value of the upstream area of the Ciliwung Watershed was 17,467.61 million US$, of the midstream area 29,227.39 million US$ and of the downstream area 41,720.43 million US$. The per capita income of the upstream area of the Ciliwung Watershed was 0.00169 $year^{-1}$ million US$ and would increase until 113% in the next 30 years. The per capita income of the midstream area of the Ciliwung Watershed was 0.00154 million US$ $year^{-1}$ and would increase until 105% in the next 30 years. The per capita income of the downstream area of the Ciliwung Watershed was 0.01382 million US$ $year^{-1}$ and would increase until 104% in the next 30 years.

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