

# The economic benefits of vegetation in the upstream area of Ciliwung watershed

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**Abstract.** Ciliwung watershed has strategic values since its entire downstream area is located in the Special Administrative Region of Jakarta (DKI Jakarta), the capital of Indonesia. This causes forest and farmland areas are converted into open areas or built-up areas. The existence of these areas provides enormous environmental and economic benefits. Economic benefit values are very important to be considered in developing a policy development plan, but they have not been calculated yet. This study aims to determine the economic benefits provided by trees and other vegetation and develops a development policy that takes into account simultaneously ecological and economic aspects. The study is conducted in the upstream Ciliwung watershed, by using land cover patterns in 1989, 2000, 2010 and 2014, and employs GIS and CITY green analysis. The results show that conversion of forest and farmland areas reduces the ability of Ciliwung upstream watershed to store water. Therefore, its ability to reduce the flow of surface has been decreased. This creates a decrease in the cost savings of annual stormwater, from US\$ 15,175,721 in 1989 to US\$ 13,317,469 in 2014. The Environmental Services Payment Policy (PES) for upstream community groups managing the watershed has been considered as a fairly effective policy.

## 1. Introduction

The development activities in the Ciliwung watershed are growing rapidly due to the influence of Jakarta city as the capital of Indonesia which is situated in the downstream area of the Ciliwung watershed. The upstream area which is located in Bogor Regency and Municipal is a tourism destination area that caused rapid development of recreation facilities. Meanwhile, the midstream area is located in Bogor Regency and Municipal, and Depok Municipal, and the entire downstream area is located in the Special Administrative Region of Jakarta (DKI Jakarta) which has dense settlement, public facilities, and other urban solid areas. This rapid growth and progress lead to various problems in the Ciliwung watershed such as worsen flooding and the deterioration of river quality [1].

Flooding is caused by the lack of water catchment areas because land cover in the Ciliwung watershed area is dominated by built-up areas. Flood has disrupted various public economic and social activities and caused huge losses. Great floods which occurred in 2002 have led to a loss of Rp 9.8 trillion (US\$7 billion) [2]. Great floods in January 2013 claimed 20 lives, and 33,502 people were forced to flee, with an estimated loss of Rp. 20 trillion (US\$20 billion) [3] with an average annual loss around US\$ 321 million [2].

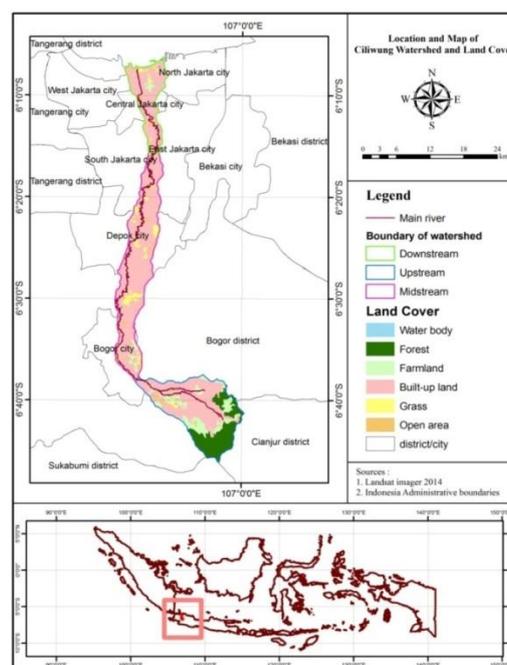
The government policy in flood control is dominated by a structural policies, such as the construction of dam, ponds, lake as well as green well and water body normalization. This policies turned out to be inefficient [4] and is not cost-effective for ecological improvement [5]. Spatial plan



is one of the non-structural approaches to flood control [6], since inappropriate changes in land use and land management are the causes of flooding [7]. Actually, spatial plan has already been stipulated in the Spatial Plan (RTRW) of regency/municipal, but its implementation is often not in line with the rapid development activities, including in the Ciliwung watershed area. Increased demand for space is driven by the increase in population and the development of various economic sectors. Up to now, the demand for space is being fulfilled by converting agricultural and forest areas into open areas or even built-up areas. This happens because the economic appreciation of forest and agricultural land is lower than that for other uses.

The low economic appreciation occurs because we have not had a tool to interpret the economic benefits of forest and other vegetation areas. A study on economic contribution of forest and other vegetation areas should be conducted to be used as a reference by the government to prepare development policies. The forest's function in slowing down rainwater runoff, increase air quality and reduce energy used to cool down air temperature can be interpreted as real saving cost to improve urban population health and welfare [8]. Based on this situation, this research intends to investigate the economic and environmental benefits provided by trees and other vegetation and to prepare policy development plan that would take into account both ecological and economical aspects.

## 2. Method



**Figure 1.** Ciliwung watershed location

This research is conducted in the upstream area of the Ciliwung watershed in Bogor Regency and Municipal. The Ciliwung Watershed covers an area of 386.10 km<sup>2</sup> spans along a 117 km main river. The watershed extends from West Java Province in the south to Jakarta Province in the north with an overall river length of 807.93 km.

The study used secondary data consisting of land cover map in 1989, 2000, 2010, and 2014 [9], administrative boundary map, watershed boundary map, annual rainfall data, and construction cost [10]. The study was conducted in two-stage analysis, i.e. the change in land cover and CITYgreen analysis. Analysis of land cover pattern change used data from landsat 7+ETM satellite image in 1989, 2000, 2010, and 2014 which identified (interpreted) land cover pattern in the upstream area of the

Ciliwung watershed using ArcGIS 10.1 [9]. Based on image classification, land cover is grouped into seven patterns which include water body, built-up areas, grass areas, open areas, dryland farming areas, forest areas, and paddy field areas in the upstream areas. CITYgreen is a comprehensive tool to calculate the environmental benefits provided by urban trees and to model the impact of various construction and planning scenarios [8]. CITYgreen 5.4 is an extension of ArcView GIS software that can calculate the environmental benefits of a particular site; one of which is to reduce the impact of surface current from rainwater (stormwater control analysis). The output of CITYgreen used in this research is the economic benefit summary.

### 3. Results and Discussions

#### 3.1. Economic benefits

Ciliwung watershed area has become a densely populated area since a long time ago, because since 1989 the land use pattern is dominated by built-up areas. Ciliwung has been essential to human life since the beginning of the history of Indonesia, and since the 10th century Kalapa harbor has been established. As time passes, the number of people residing around the Ciliwung River continues to grow and develop. This is why the community needs for housing and other facilities continues to grow until now. Based on the analysis of land cover patterns from 1989 to 2014, the built-up areas in the upstream areas has increased from 6,269.74 ha in 1989 to 7,844.23 ha in 2014. Most of the land that can serve as water catchment areas have largely been reduced, the extent of forest area decreased from 4,614.16 ha in 1989 to 4,241.21 ha in 2014. The land cover patterns from 1989 to 2014 in the Ciliwung watershed area are presented in table 1.

**Table 1.** Land use pattern in upstream Ciliwung watershed

Land use pattern	Year 1989		Year 2000		Year 2010		Year 2014	
	Ha	%	Ha	%	Ha	%	Ha	%
Water body	35.94	0.24	78.08	0.51	96.75	0.64	64.09	0.42
Built-up areas	6269.74	41.21	6334.67	41.64	6665.10	43.81	7844.23	51.56
Grassland area	124.12	0.82	116.92	0.77	148.86	0.98	113.10	0.74
Open areas	187.97	1.24	276.49	1.82	186.35	1.22	224.70	1.48
Dryland farming areas	3257.09	21.41	3158.62	20.76	3009.34	19.78	1914.30	12.58
Forest areas	4614.06	30.33	4521.74	29.72	4390.38	28.86	4241.21	27.88
Paddy field areas	725.82	4.77	728.21	4.79	717.96	4.72	813.11	5.34
Total	15214.74	100.00	15214.74	100.00	15214.74	100.00	15214.74	100.00

Within this 25-year period, the proportion of built-up areas has increased from 41.21% of the total area in 1989 to 51.56% in 2014, or up by 10.35 %. In 1989, the proportion of dryland farming areas was 21.41% and was reduced to about 12.58% in 2014, or down by 8.83%. There was a slight increase in paddy field proportion of 0.57%, from 4.77% in 1989 to 5.34% in 2014. The proportion of grassland areas was reduced by 0.08% , while open areas and water body was increased by 1.24% and 0.18%

Based on the land use pattern, the proportion of dryland farming areas suffered the largest decline compared to other use pattern as water catchment areas. Agriculture land owners can easily convert their agricultural land because the economic benefits provided by agricultural land is lower than that of other uses. The benefits of land that is widely understood until now is only as a medium for production, while other benefits including as ecological balancer is often overlooked. Meanwhile, the presence of paddy fields in the watershed areas have three major benefits, namely (1) as a medium for paddy production, (2) as a buffer of environmental quality and ecological balancer, (3) provide

nutrients to ground water, maintain the river flow, reduce runoff, and weather stabilization [11]. Thus, a policy to preserve agricultural land is needed.

CITYgreen is able to analyse the statistical results of the site which consists of land cover distribution and the extent of each of land cover, as well as the ecological benefits consisting of Current Number (CN), run off, storage volume needs, construction cost, and annual stormwater saving cost. In this research, the analysis is focused on economic benefits. There are two types of CN produced by CITYgreen, namely CN and CN Without trees. CN is actual CN value based on real land cover, while CN Without Trees is CN value based on a scenario of zero tree in the study area.

The result of the analysis shows that there was an increase in CN from 2000 (82) to 2010 (88), and a decrease in CN from 2010 (88) to 2014 (85). This means that in the upstream area of the Ciliwung watershed, there was an increase in run-off from 2000 to 2010, and a decrease in run-off from 2010 to 2014. The storage volume capacity of the upstream area of the Ciliwung watershed decreased from 1989 to 2014. This occurred because there was a change in the extent of canopy land cover (forest and agriculture land) to urban solid areas, which was demonstrated by the Curve Number (CN) value that tends to increase each year. The bigger the water storage volume capacity in the upstream area of the Ciliwung watershed, the higher the annual stormwater saving cost will be. The tabulation of the result of CITYgreen analysis is presented in table 2.

**Table 2.** The result of CITYgreen analysed

Information	Year			
	1989	2000	2010	2014
CN (Current)	82	82	88	85
CN (Without trees)	88	88	93	90
Run off (Current, cm)	11.48	11.48	14.65	13.03
Run off (Without trees, cm)	14.65	14.65	17.61	15,81
Storage volume needed (m <sup>3</sup> )	1.90E+15	1.90E+15	1.78E+13	1.66E+12
Construction cost (USD)	\$174,064,321	\$174,064,321	\$163,407,322	\$152,750,322
Annual stormwater saving cost (USD)	\$15,175,721	\$15,175,721	\$14,246,595	\$13,317,469

The decrease in storage volume needed from 1.90E+15 in 2000 to 1.78E+13 in 2010, and to 1.66E+12 in 2014 can be interpreted as a decrease in the capability of the upstream areas of the Ciliwung watershed as a water volume storage to reduce surface current. The decline reduced the economic value of benefit which is stated as annual stormwater saving cost, where annual stormwater saving cost is the annual cost based on financing of more than 20 years with 6% interest rate. In 2000, the annual stormwater saving cost was \$15,175,721; it decreased to \$14,246,595 in 2010, and further decreased in 2014 to \$13,317,469.

The economic value of benefit is the dollar value of benefit calculated by multiplying storage volume needed of stormwater reduced by trees by a local cost per cubic foot for mitigation [8]. For example, the cost for building retention ponds, building additional stormwater management facilities or treating water. Additional information used to obtain economic value of benefits is the unit construction cost using general cost unit standard in 2015 and construction material cost in 2015 [12].

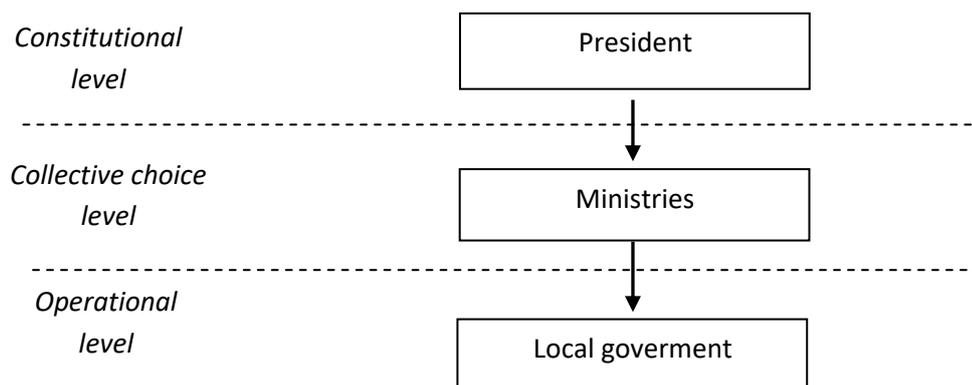
The decrease in economic value of benefit from 1989 to 2014 was directly proportional with the decrease in the extent of forest and agriculture areas. Therefore, adjustment of efficient land use pattern is needed to harmonize urban economic development and urban ecological function to attain efficiency of more environmentally friendly land use [13]. Land use types influence the ecological benefit of a city, with the highest benefit value being land use as green open space, residential areas, roads, and industrial squares [14]. Hence, city forest and green open space need to be developed through fiscal planning process, systematic design, and management to give benefits to urban areas [15].

The Ministry of Forestry used their budget fund for Jakarta flood handling program in 2014 amounted to USD 114,543,000. The program's activities and their respective allocations are as

follows: permanent vegetation (0.01%), agroforestry (0.2% 0), gully plug (0.02), controlling dam (0.54%), retaining dam (0.37%) and green well (98.85%). Compared to the value of annual stormwater, the allocation for maintaining vegetation carried out by the Ministry of Forestry is bigger reaching USD 24,054,030. Compared to the budget allocation for physical development, the budget allocation for maintaining vegetation is much smaller. With continuous outreach activities on the economic value of benefits of forest and other vegetation areas, the budget allocation for maintaining vegetation is expected to increase.

### 3.2 Development policy

Watershed is classified as common pool resources (CPRs) based on its rivalness and exclusivity nature. Subtractibility or rivalness means that individual's consumption of resources will reduce the ability of others to use those resources. Exclusivity means that there are costs spent to limit the access to resources for others that can be designated as beneficiaries. Overuse and free rider are both problems and characters of CPR resources; thus, mechanism and institutionalized system are needed to prevent or avoid them. Therefore, watershed management in the development countries has to be started from institutional arrangement through a detailed mechanism to overcome imbalance of access to water and the recognition of the right to access water for poor population [16].



**Figure 2.** Government institution position in Ciliwung watershed management [17]

Payment for Environmental Service (PES) mechanism can be done to prevent farmers from doing land fragmentation and land conversion through economic incentives [18]. PES needs to be implemented as joint activities between the government and the public, starting from the transfer of knowledge on the economic benefits of forest and agriculture areas. Institutional approach for Ciliwung watershed management can be done by referring to Ostrom's *Institutional Analysis and Development* (IAD) [19]. IAD framework is a mapping of various concept levels as a means to systematically understand the policy setting process, to analyze institution that prepares collective action as a basis to determine activities and result accomplishment. PES mechanism implementation needs a collective action involving many institutions, both governmental and non-governmental. The rules at collective choice level consist of several laws and regulations that are under the authority of some ministries presented in figure 1.

The ministries responsible at collective choice level are the Ministry of Environment and Forestry, the Ministry of Public Works and Public Housing, Ministry of Spatial Plan and Agrarian Affairs, and the Ministry of Agriculture. Regulations at operational level is Regional Regulation on Spatial Plan issued by each Regency or Municipal. Institutions responsible for this are Local Governments of Regency or Municipal consisting of Bogor Regency and Municipal, Depok Municipal, and DKI Jakarta.

Efforts to reduce Ciliwung discharge rate to a safe condition can be conducted by implementing four scenarios, PES payment, PES payment in the form of access to market, reforestation, and land conversion prevention [20]. Institutions related to these scenarios are at collective choice level and

operational level. Incentive mechanism is in the form of compensation and environmental service compensation. PES policy can gradually maintain agriculture area and reduce river current discharge if PES policy is implemented in the form of guarantee of access to markets, and run along with measures on land conversion and tree reforestation policy [20]. Reforestation policy can be implemented without compensation mechanism because the status of forests in the upstream area is a state forest. However, PES must be given to the community or people who lose their access due to the designation of the forest area [21]. For example, the community living around the forest in Ejidatarios and Pobladores Mexico receives compensation with some limitations such as, ban of forest clearance, hunting and habitat change, and the obligation to limit the number of livestock, conduct patrol, and control of erosion. The Mexican experience can serve as an example to implement compensation in forest area in the upstream area of the Ciliwung watershed. The community living in the upstream area are the most effective watershed managers. The next challenge is how PES can increase poor population's welfare in the upstream area of the watershed.

#### 4. Conclusions

The economic value of benefit is the dollar value of benefit calculated by multiplying storage volume needed of stormwater reduced by trees by a local cost per cubic foot for mitigation. This value is the annual stormwater saving cost value that tends to decrease during this research. In 2000, the economic value of benefit of forest and agriculture areas was \$15,175,721; it decreased to \$14,246,595 in 2010, and further decreased in 2014 to \$13,317,469. The economic benefit should be made known to the government and the public in order to understand the importance of forest and agriculture areas. The most effective way to maintain forest and agriculture areas is the implementation of PES mechanism for citizens who manage the watershed in the upstream area. PES policy needs a collective action involving many institutions, both governmental and non-governmental.

Public participation in watershed management should be on the top of the government's agenda. Communication and information dissemination related to the importance of payment for environmental services should become the government's agenda, by involving educational institution, research and public organization to accelerate the people's understanding process.

#### Reference

- [1] Poerbandono P, Ward PJ and Julian MM 2009 Set up and calibration of a spatial tool for simulating river discharge of Western Java in recent decades : preliminary result and assessments *Journal of Engineering and Technological Sciences* **41**(1): 50-64
- [2] Budiyo Y, Aerts J, Brinkman J, Marfai MA and Ward P 2015 Flood risk assessment for delta mega-cities: A case study of Jakarta *Natural Hazard* **75**(1) pp. 389-413 American Forest 2002 CITYgreen 5.0 user manual American Forest Washington DC
- [3] Kompas 2013 <http://forum.kompas.com/megapolitan/231945-'inilah-kerugian-akibat-banir-jakarta-dari-tahun-ke-tahun> [Are these economic loses of Jakarta flooding?]', html, 23-01-13 Retrieved on May 1, 2015. Jakarta – Indonesia
- [4] Fulazzaky MA 2014 Review challenges of Integrated Water Resources Management in Indonesia *Water* **6**:2000-20
- [5] Cui B, Wang C, Tao W and You Z 2009 River channel network design for drought and flood control: A case study of Xiaoqinghe River basin, Jinan City, China *Journal of environmental management* **90**(11): 3675-3686
- [6] Kodoatie R J and Sjarief R 2010 *Tata Ruang Air* [Water Land Use] ANDI Publisher Yogyakarta Indonesia
- [7] Woube M 1999 Flooding and sustainable land–water management in the lower Baro–Akobo river basin, Ethiopia *Applied Geography* **19**(3): 235-51
- [8] American Forest 2002 CITYgreen 5.0 user manual American Forest Washington DC

- [9] Saridewi TR 2015 *Instrument pembayaran jasa lingkungan dalam mendukung penataan ruang DAS Ciliwung* [Payment for environmental services for supporting land use planning in Ciliwung Watershed] Dissertation Bogor Agricultural University Indonesia
- [10] Central Management of Citarum Ciliwung Watershed (Balai Pengelolaan Daerah Aliran Sungai Citarum Ciliwung) 2011 *Penyusunan rancangan peningkatan fungsi dan daya dukung ekologi dalam pengelolaan DAS Ciliwung* [Drafting improved functionality and ecology in the management capability Ciliwung Watershed] Bogor, Indonesia
- [11] Wu R-S, Sue W-R, Chien C-B, Chen C-H, Chang J-S and Lin K-M 2001 A simulation model for investigating the effects of rice paddy fields on the runoff system *Mathematical and computer modeling* **33**(6): 649-58
- [12] Hasanah A 2016 *Kajian hubungan perubahan penutupan lahan dan kapasitas pengendalian aliran permukaan pada lanskap DAS Ciliwung hulu* [A relation study between landcover change with stormwater runoff control capacity in Ciliwung Upstream Watershed landscape] Thesis Bogor Agricultural University Indonesia
- [13] Zhang K, Zhang J, Chen Y and Zhu Y 2006 Urban greenbelt eco-service value of Hangzhou City under effects of land use change : An evaluation with CITYgreen model *Chinese Journal of Applied Ecology* **17**(10):1918-22
- [14] Peng, L, Chen, S, Liu, Y and Wang, J 2007 Application of CITYgreen model in benefit assessment of Nanjing urban green space in carbon fixation and runoff reduction *Chinese Journal of Applied Ecology* **18**(6):1293-98
- [15] Wolf, KL 2003 Ergonomics of the city : Green infrastructure and social benefits In C. Kollin (ed) *Engineering Green Proc of the 11th National Urban Forest Conference* American Press Washington DC
- [16] Molle F, Wester P and Hirsch P 2010 River basin closure: Processes, implications and responses *Agricultural Water Management* **97**(4): 569-77
- [17] Ananda J and Proctor W 2013 Collaborative approaches to water management and planning: An institutional perspective *Ecological Economics* **86**: 97-106
- [18] Muradian R, Corbera E, Pascual U, Kosoy N and May PH 2010 Reconciling theory and practice: An alternative conceptual framework for understanding payments for environmental services *Ecological economics* **69**(6) pp 1202-08
- [19] Ostrom E and Cox M 2010 Moving beyond panaceas: a multi-tiered diagnostic approach for social-ecological analysis *Environmental Conservation* **37**(04) pp 451-63
- [20] Saridewi TR, Hadi, S, Fauzi A and Rusastra IW 2017 Payment for Environmental Services Approach to Reduce Flood in Ciliwung Watershed *Biotropia* **24**(2) pp 127-39
- [21] García-Amado LR, Pérez MR, Escutia FR, García SB and Mejía EC 2011 Efficiency of payments for environmental services: equity and additionality in a case study from a biosphere reserve in Chiapas, Mexico *Ecological Economics* **70**(12) pp 2361-68