# Dynamic Model for Settlement Area Management In the Upper Stream of Ciliwung Watershed, Bogor District – Indonesia

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## ABSTRACT

Ciliwung watershed is one of the most critical watersheds in West Java Province. The upper stream of Ciliwung watershed lies in the Bogor District, which is an important function for the surrounding areas. The upper stream of Ciliwung has regulated or managed water resources supply, whether there is flooding or drought in the middle and the down stream. Ecosystem degradation in the upper stream of Ciliwung watershed was caused by land use change from the forest and agricultural land to settlement utilization. Holistic and effective management of settlement areas is needed in order to be in accordance settlement growth with the carrying capacity of watershed. The objective of the research was to design a model for managing the settlement areas. The research method used the dynamic system approach with software powers in 25d, for a 20 years simulation. The result showed archetype of the model is Limit to Growth modél and coordination as the leverage factor for managing settlement area. Simulation with increasing coordination, combined with increasing consistency for regulation, people participation and decreasing population growth rate would increased performance of the upper stream of Ciliwung watershed.

**Keyword:** Ciliwung, Dynamic model, Settlement, Watershed

## 1. INTRODUCTION

Ciliwung watershed is one of many critical watersheds in West Java Province-Indonesia. Ecological function as ecosystem services provider was come through degradation. Degradation of watershed function occurred by growth of settlements in the upper stream of Ciliwung watershed was very rapidly and tends to be uncontrolled. Ssettlement area at the upper stream of Ciliwung watershed increased from 5,10% (1990), to 20,13% (2006). Settlement was not only located in the settlement area but also in the protected area as forest and riparian zone of Ciliwung river.

Based on Government Regulation (PP No. 26/2008) concerning spatial planning of nasional region (RTRWN), and Presidential Regulation (Perpres No 58/2008) regarding spatial planning of Jakarta-Bogor-Depok-Tangerang-Bekasi-Puncak-Cianjur (Jabodetabekpunjur) region, the upper stream of Ciliwung watershed is a part of the national strategic region, which required rehabilitation and revitalize its function as water resource and soil conservation. Goals of spatial planning in Jabodetabekpunjur region is to realize carrying capacity of sustainable watershed in managing region to ensure water and soil conservation, availability of ground and surface water and tackled flood. Therefore, growth of settlement in the upper stream of Ciliwung watershed is needed in order to concordance with carrying capacity of watershed.

Settlement problems in the upper stream of Ciliwung watershed are complicated issues. It is caused by inconsistency of regulation, there are multi-stakeholders, and community participation to improve carrying capacity of environment were indicated middle to low. Inconsistency on policy implementation was caused by the coordination and communication among various stakeholders is not running well.

Dynamic system as comprehensive and integrated thinking was able to simplify complex issues without losing the substantial items (Muhammadi *et al,* 2001). Dynamic system could be analyzed the structure and behavior patterns of complex systems, changed rapidly and contained uncertainty (Muhammadi *et al.*, 2001), and structural changed that occurring in one part of the system that will impact on the overall system behavior, could be analyzed quickly (Martin, 1997). The process of analysis the dynamic system using simulation model was done quickly, and comprehensively, (Muhammadi *et al.*, 2001; Meadows *et al.*, 2004; Forester, 1976).

In order to solve the settlement problems as increased of settlement needs, non smooth of coordination, and decreased of watershed carrying capacity, the dynamic model could be used through various scenarios to make systemic changed towards desired goal through various experiments using simulation model.

The objective of the research was to design a model for managing settlement area with using dynamic model. The result of the research are expected to give useful information for spatial planning (RTRW) and watershed management especially in upper stream of Ciliwung watershed.

## 2. MATERIAL AND METHODS

Study sites was located in the upper stream of Ciliwung watershed, which is covered a whole of Cisarua and Megamendung Sub-Districts, a part of Ciawi Sub-District, a part of Sukaraja Sub-district, and a part of Bogor City (14.793,32 ha). It's laid on longitude $106^0 50'50''$ up to $107^0 0'40''$ and latitude E $6^0 36'10''$ up to $6^0 47'0''$ (Figure 1).

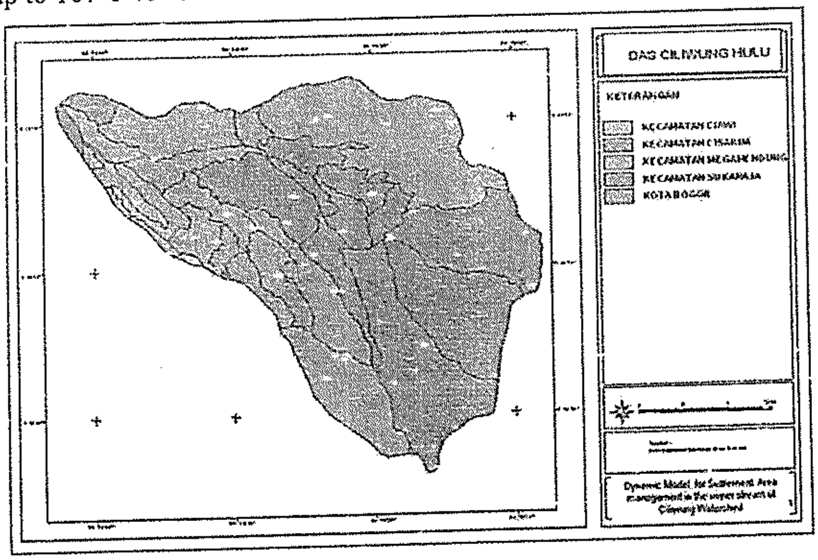


Figure 1. The upper stream of Ciliwiung Watershed

Primary and secondary data were used to build the model. The whole process was conducted by using Powersim Software version 2.5d. constructor.

The stages of analysis, as follows:

(a) Identification of the system and the causal loops

(b) Model Validation: Validation test for looking performance of dynamic model used statistic test AME, AVE (threshold 10%), Kalman *Filter* (threshold fit was ranged on 47,50 up to 52,50%) and Durbin Watson (DW>2 sharp; DW<2 fairly sharp) (Muhammadi *et al.*, 2001).

(c) Model verification used *limit to growth* concept (Meadows *et al.*, 2004) to population element as a part of aggregate model. Model verification was held due to the aggregate and a part of aggregate model have similar pattern if they were simulated (Muhammadi *et al.*, 2001). Test of model sensitivity was done by giving stimulation to several model parameters as coordination, consistancy to regulation, community participation, birth and inmigration rate.

(d) Simulation model was done by four scenarios for 20 years, i.e. started from 2010 up to 2030.

## 3. RESEARCH RESULTS

### a. Identification of the System and Causal Loops

Population growth was occurred by birth/death and migration. Increasing population caused the increase of land needs for settlement. Weak of government's commitment and low community participation are driven factors, which caused uncontrolled of settlement growth. Some settlement area penetrated to the unsuitable area for settlement, i.e. protected and agriculture areas. The increase of land needs of settlement added the impervious lands area. This consequence, water run off from settlement area was increased. On the other hand, the population density, settlement density and the amount of domestic waste was also increased. Water run-off from the settlement, the amount of settlement waste and the quality of physical environment of watershed were decreased. Decreased quality of physical environment is added by the lack of community participation, reduce environment health, and affected the rate of birth and death. Based on this identification, causal loop diagram was established (Figure 2).

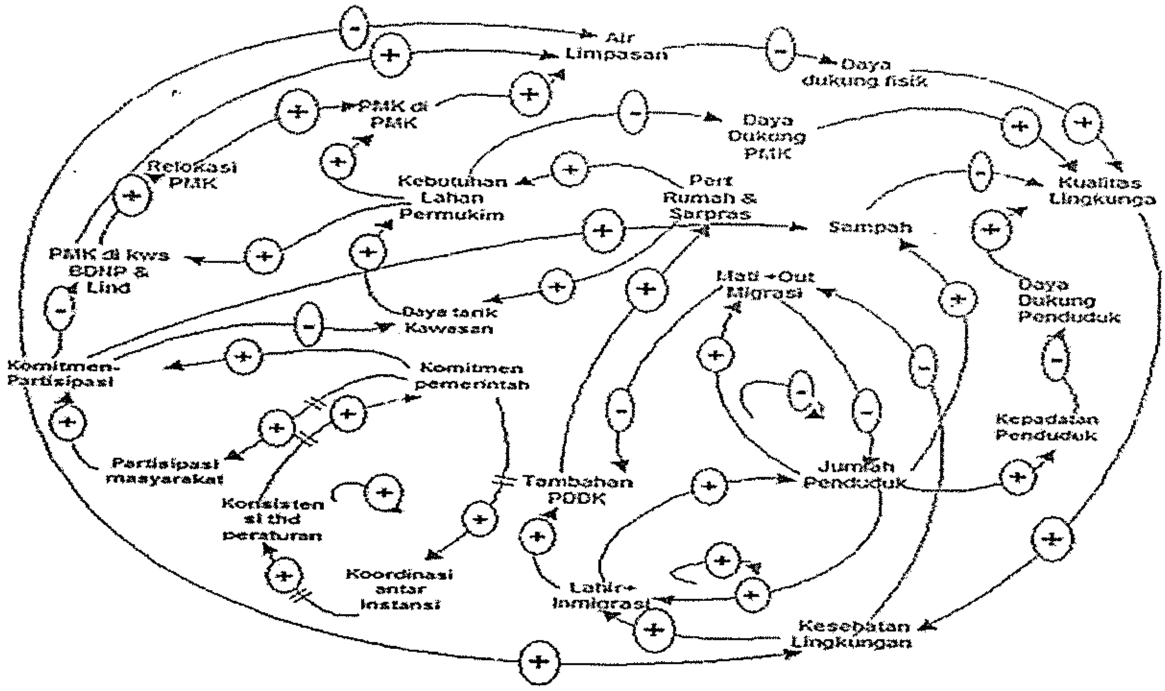


Figure 2. Causal loop of settlement area management in the upper stream of Ciliwung Watershed

### b. Model Validation

Validity test using statistical methods AME, AVE, KF and Durbin Watson was done for total population element. The results of validity test for total population element indicated that the population of the model with empirical data was appropriated in the threshold allowed. The average value (AME) and variations value (AVE) is 0.178% (appropriate), means the model could be received. So, as to the value of KF is 50% (appropriate) and the value of DW = 0,591 (the pattern is less sharp fluctuations) (Figure 3).

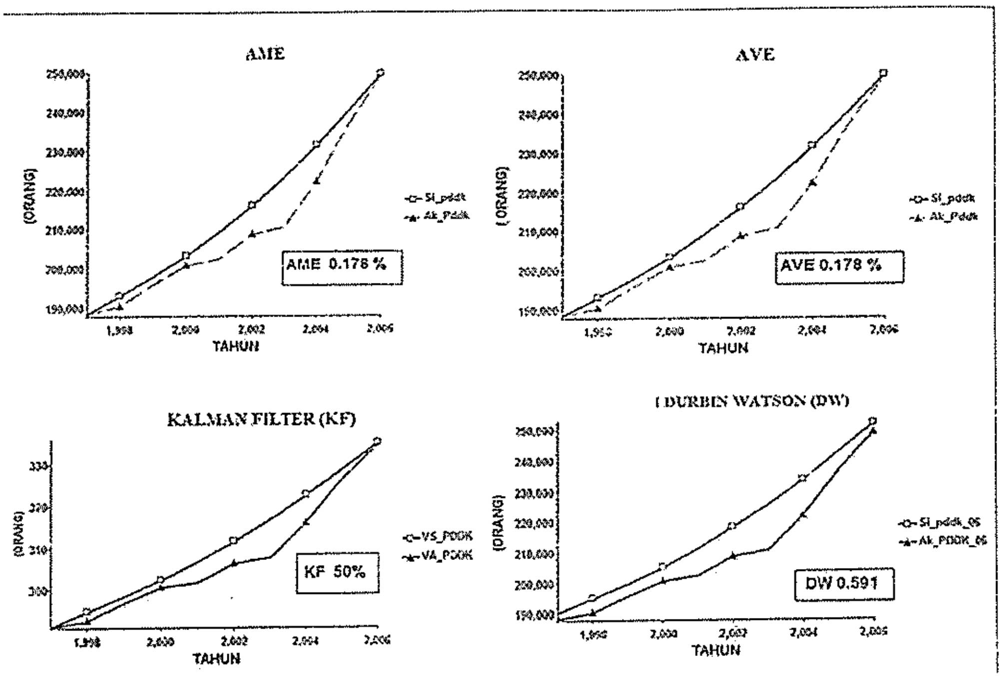


Figure 3. Validity test for population element with AME, AVE, Kalman Filter, Durbin Watson

### c. Model Verification

Simulation results showed the element of the population has formed S curve. At first population element showed the growth process by reinforcing of the positive loop structure. But with increasing time, has occurred balancing by negative loop structure. The pattern of the population growth followed the concept of Limit to Growth (Meadows et al, 2004) with settlement area as constraint factor. Based on the shape and structure, the dynamic model of settlement in the upper stream of Ciliwung watershed showed archetype Limit to Success (Kim and Anderson, 1998; Tasrif, 2006).

### d. Model Sensitivity

Based on sensitivity test, it could be concluded that coordination parameter is high sensitivity. Therefore, to be leverage factor because of the highest affect for population and the settlements parameters. While sensitivity of the birth rate and in migration parameters was lower than coordination, consistency and public participation parameters (Table 1).

Table 1. **Sensitivity**

| Parameter | Intervention | Sensitivity | |
|---|---|---|---|
| | | **Population (%)** | **Land Settlement (%)** |
| a. Rate of birth and in migration | 2 % | 19,691 | 22,012 |
| b. Coordination | 100% | **30,165** | **31,187** |
| c. Consistensy | 100% | 30,161 | 31,188 |
| d. Community Participation | 80% | 28,609 | 29,443 |

### Simulation

Four scenarios of model simulation are, as follows:

(a) No intervention (TI).
(b) Population Control (PP): intervention was given to birth rate and in-migration rate; it was carried out by decreasing their rate into 2%

(c) Strengthening Government (PK): intervention was given to coordination and parameter consistency with increasing their value up to 100%
(d) Public Empowerment (PM): intervention to community participation parameter was carried out by increasing its value up to 80%.
(e) Combined population control, strengthening government, and community empowerment (KPM): intervention was carried out by decreasing birth and in-migration rate to 2%, by increasing coordination and parameter consistency up to 100%, and by increasing community participation parameter up to 80%.

Without intervention (TI), performance of the upper stream of Ciliwung watershed in 2030 would be decreased. It is showed by the highest growth of population (Figure 4a), land needs for settlement (Figure 4b), domestic waste (Figure 4c), run off (Figure 4d) and unsuitable region for settlement (Figure 4e). Analysis with intervention showed performance of the upper stream of Ciliwung watershed would be improved, i.e. population increasing (Figure 4a), land needs for settlement (Figure 4b), number of domestic waste (Figure 4c), run off (Figure 4d) and unsuitable region for settlement (Figure 4e) were lower.

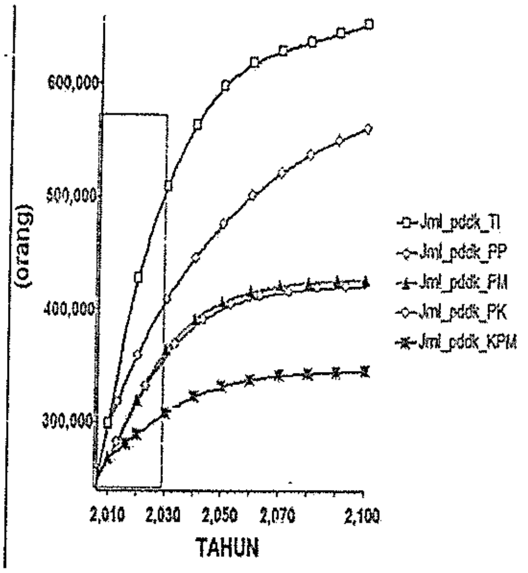


Figure 4a. Population

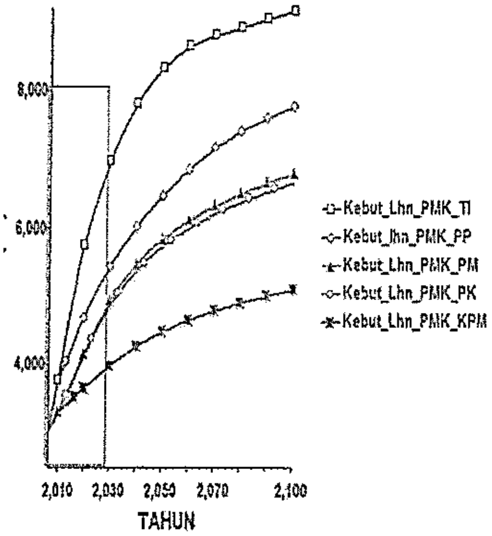


Figure 4b. Land needs for seetlement

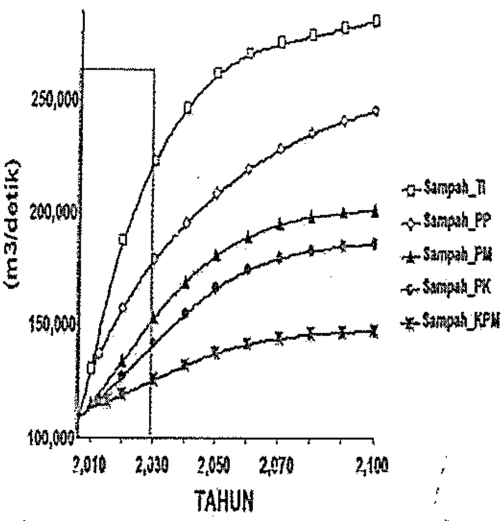


Figure 4c. waste from settlement

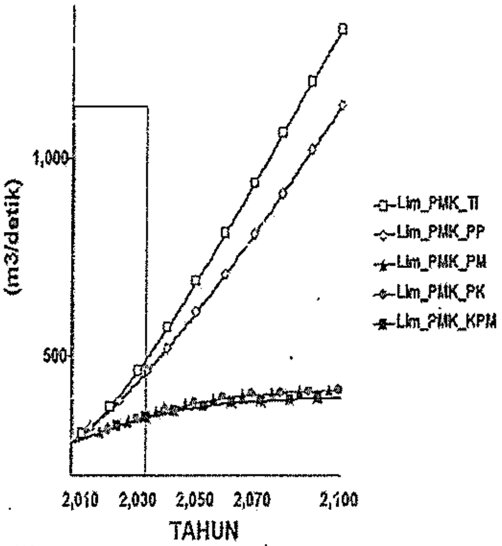


Figure 4d. Run-Off from setttlement

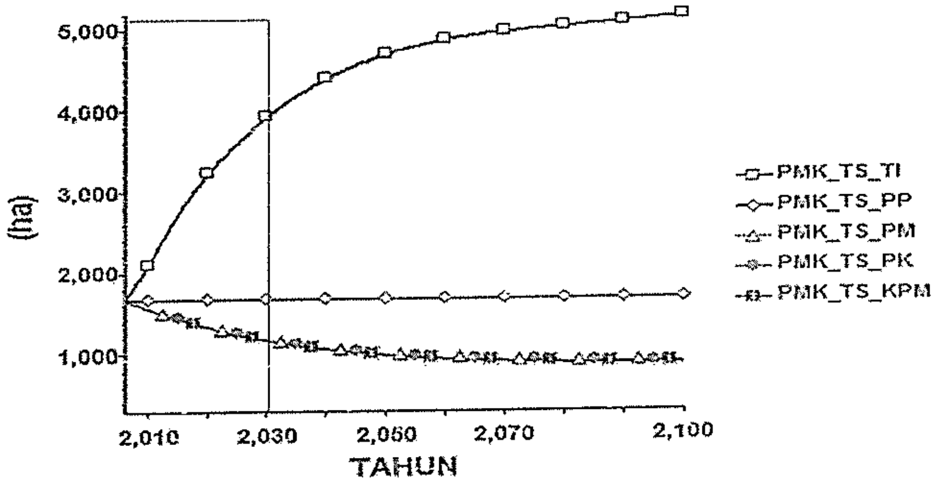


Figure 4e. Setttlement in unsuitable area

The highest intervention impact to indicator of settlement area management is reduced of settlement in the unsuitable region at the range about 57,19-70,05%. Meanwhile population control (PP) scenario is the lowest impact to indicator of settlement area management, especially for run off from settlement (5, 68%) (Table 2). The best intervention impact to indicators of settlement area management is KPM Scenario. Collaboration between government and community in KPM scenario reduced land needs 42,87%, population 39,38%, unsuitable region for settlement 70,05% (Table 2).

Table 2. **Impact of Scenarios to Indicators of Settlement Area Management**

| No | **Indicators of Settlement Area Management** | **KPM (%)** | PK ( %) | PM (%) | PP(%) |
|---|---|---|---|---|---|
| 1 | Population | 39,38 | 30,07 | 28,54 | 19,70 |
| 2 | Land needs for settlement | 42,87 | 31,07 | 29,36 | 19,69 |
| 3 | Settlement in the unsuitable region | 70,05 | 69,70 | 69,94 | 57,19 |
| 4 | Run off from settlement | 30,59 | 30,17 | 29,91 | 5,68 |
| 5 | Waste from settlement | 43,54 | 36,40 | 31,35 | 19,69 |

## 4. DISCUSSION

Sensitivity analysis showed parameters, which related to institutional (coordination, consistency and community participation). It is leverage factors to increase performance of the upper stream of Ciliwung watershed. Scenarios PK, PM and KPM were showed that improved institutional decreased volume of run off from the settlement (Figure 4d) and decreased settlement area in the unsuitable region (Figure 4e). This condition indicated that management of settlement in the upper stream of Ciliwung watershed requires improvement of institutional performance, which is related to spatial planning. Weak coordination caused spatial planning that should be as a tools for coordinating development (Wirojanagud *et-al*, 2005) and tools for promoting sustainable development (Brackhahn and Kärkkäinen, 2001) will be not worked.

The best scenario of KPM shows that collaboration between government and community is quite effective in order to reduce population, the needs of area settlements, and settlement in the unsuitable region. Settlement relocation from unsuitable region (protected area) to suitable region for settlement should be involved community participatory, actively.

## 5. CONCLUSION

Structure of dynamic model for settlement area management is limit to success. The limiting factor for settlement growth is physical condition of the upper stream of Ciliwung Watershed. The best scenario is collaboration government-community (KPM). Strengthening the government needed to make coordination among stakehoiders, both at the central and iocal levels could be smooth. While community development is the effort to increase community participation in managing the settlement to support carrying capacity of the watershed.

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