# Call for Papers
# Application of System Dynamics on Watershed Management in Java Island, Indonesia

By
Prasetyo **Sunaryo,** Tusy A. **Adibroto,** Hary **Budiarto**, and Ervan **Maksum**
*Researcher for the Agency for the Assessment and Application of Technology (BPP Teknologi)*

*ABSTRACT*

*The sustainability of a Watershed (DAS) ecology depends on numerous factors, especially land and water availability. Transformations occurring on a DAS be seen from the forest openings in the upstream to the conversions of rice fields into settlements and industrial area in the downstream. These transformations determine the water sycle of a DAS, such as soil absorbency, thereby affecting the eiver's waterflow and quality. Mismanagement on the upstream area, in addition, may affect the downstream area.*

*This paper is aimed to observe and understand the occurring transformations on DAS in Java Island - Indonesia., thus provide the basic considerations for well-managed DAS in order to minimize any possible negative impacts. System Dynamics program is applied to support the analysis.*

## I. INTRODUCTION

Watershed (DAS) is actually the land stretching along a river. DAS in this paper is devided in to three parts :

a) Upstream DAS; covering forests, farmland/ricefields, and settlements
b) Downstream DAS; covering settlements, farmland/ricefields and industrial area
c) Middle DAS; the transitional area between the two.

Therefore, a DAS area streches from mountainous to coastal area regardless any administrational borders. The DAS model applied here is conducted through a dynamic model analysis of which data is taken from Indonesian Statistic Bureau (BPS) and from the Study of Sustainable Development.

Due to its physical and enviromental complexity as well as its significant role for the on living creatures, DAS is obviously one of the strategic natural resources. Its function is determined by various biphysical components such as land utilization, soil and other physical characteristics on its surface. These components, thus, should be maintained and well-balanced to establish a good supporting DAS. A DAS sustainability in this paper depends on two factors, i.e. the transformation of a) Land utilization and b) water utilization (considering its function as a water provider). On the other hand, DAS as a waste container is not considered here, since waste is another specific and complicated problem of its own.

This paper, indeed, focuses on the natural and enviromental problems in Indonesia as the impacts of four economic tendencies :

1. Rapid population growth
2. Sharp economic growth within the last two decades, mainly caused by oil productions and exports of other natural resources.
3. Tremendous expansion of food production, indicated by the quick industrialization and economic growth in Java island
4. Extensive land exploitation, which often endanger both uphill and downhill environment

System Dynamic is applied to understand the transformations on a DAS and in turn may serve as the foundation in carrying out suitable plans for a sustainable development.

## II. ANALYSIS

### 2.1. The Purpose of Study

1. To have feedback loop on the land water management in Java Island, hence adds to the understanding of the causal relationship in the real system (observed).
2. To find a certain ecological limit of the rapid population growth.
3. To figure out the model's sensitivity, by transforming certain parameters which identify land and water utilization conducted by people and government.
4. This model is expected to be the foundation in forming DAS management, related with utilization for industry, farming, and settlements, as the impact of rapid economic growth.
5. To find solutions to the shortage of land in Java.

### 2.2. Stucture of The Model

Description of System Dynamic on Land and Water Management in Java Island, Indonesia

The global model of land utilization in Java reveals that more than 36 DAS in Indonesia, covering 10.4 million Ha, is classified as critical land. This critical land is increasing about 1-2% per year, and about 1/3 (one - third) of it is rice fields in the downstream rice field/farmland.

Forest is the first area to deal in land utilization. Recently, many forests have been converted into rice fields, settlements, industrial area or farmland. Needless to say, more and more rice fields are needed to meet the increasing demand of rice, as the impact of economic and population growth in Java island. Furthermore, urbanization also accelerates housing demands, which consequently requires more conversions of fertile rice fields and farmland into settlements. Today, the government is building up apartments in big cities as an alternative solution. Yet still is questionable if such effor will solve the land utilization problems and thus improve the watershed management in Java. Industrial and farmland expansion are facing the same situation, since the basic problem behind it is the speedy economic and population growth.

### 2.3. Analysis

As stated above, economic growth is the most significant factor causing land conversion. Economic growth always results in the increase of primary, secondary and tertiary needs. In the farmland sub system, the needs for living (vegetables, fruit, meat) is

determined by the population growth. Forest conversion into farmland will influence soil's infiltration and percolation as the soil becomes condensed and humid.

In the rice field sub system, forests are converted into rice fields to meet the basic need (rice). In this model, agricultural intensification is assumed to be hampering the forest growth for rice fields. In rice fields, water supply comes from irrigation.

In the settlement subsystem, the available land comes from forests, farmland and rice fields. Settlement has become crucial in corelation with economic growth now, since it is not only a basic need but it has become an economic commodity.

Big investments in settlement development may spoil the land's functional structures and ecological activities. Therefore, area limitations are necessary to minimize land hardening that can avoid water infiltration. In that case, most of rainwater will only be run - off, with significant effects on the ground water supply and the river's waterflow fluctuation.

In industrial subsystem, land utilization occurs on the downstream area. Usually, this area is originated from rice fields or farmland. It is often congested with various economic facilities, such as factories and offices, which are often closed buildings. The soil, then, can not absorb the rainwater. Despite its land expansion for industry, economic growth may result in land inflation, which in turn will suppress the land expansion itself and lead to a balanced condition.

In hydrological dynamic cycle, land transformations on a DAS bring some changes to river's waterflow, as the result of run - off and sedimentation. Water volume basically remains constant, but men's activities may change the natural cycle process from the precipitation to evapotranspiration and evaporation. This will differ the water volume in each catchment area.

**2.4. Limits and Behavior of the System.**

The variables included consists of exogenous, endogenous and omitted ones. Endogenous variables comprise forests, farmland, industrial area and settlements in the beginning of simulation. Omitted variables are aimed to limit the problem analysis. Exogenous variables, expected to change the systems behavior, comprise the population growth, land prices, housing capacity, living standards, rice production (agricultural intensification) and water utilization percentage. In addition, a referencial scenario is consulted (until the year of 2070), covering the following assumptions : a) forest width converted into consumptive area (settlement, industrial, rice field) at 21%, b) increase of rice field area at 1,8% year, c) Population at 2% year (regardless the death toll), d) economic growth at 7% year, e) water supply in Java at 122,700 million m3/year, f) percentage of water sonsuption for drink at 7,3%, animal farm 0,3% and irrigation 82,4%.

**2.5. Policy Choises**

The ananlysis allows us to ecognize the land and water utilization on DAS in the future, with respect to the population, land utilization pattern and water consumption. The target of the policies is to organize land and water functional aspects, thus formulated as follows : Policy on land utilization , b) Policy on Agricultural technology, c) Policy on the water resource management and , d) Policy on the population.

## III. CONCLUSION

A number of points can be concluded from the analysis with System Dynamics :

1. Population grwth is a significant variable which influences land and water utilization.
2. Water availability is determined more by water production in the conversion area than by people's consumption. Therefore, water resource conservation can be carried out through land management in the upstream area.
3. Forest converting disturbs the hydrological system on the DAS system.
4. The increase of settlements is not much influential to the land and water functional aspects (in long term).
5. Agricultural intensification is necessary to reduce water consumption for irrigation.
6. Price is an external variable in decision making, since it is affected by supply - demand tendencies.
7. A converted forest has certain functional limit, therefore in a long term basis forest conversion speed will come to a balanced condition.
8. Industrial and settlement land utilization should proportionally organized, since it is a big ground water consuming area and yet it is not self - sufficient area in the water supplying.

## IV. BIBLIOGRAPHY


1. *Asdak, C., 1995, Hidrologi dan Pengelolaan Daerah Aliran Sungai (Hydrology and Watershed Management), UGM Press, Yogyakarta, Indonesia*
2. *Meadows D. L. and Meadows, D., 1973, Toward Global Equilibrium, Wright Allen Press, Cambridge, Massachussets, USA*
3. *State Ministry of Population and Environment, Kualitas Lingkungan Indonesia, 1995 (Indonesian Environment Quality, 1995), Jakarta, Indonesia*
4. *Statistic Bureau Centre, Statistik Lingkungan Hidup Indonesia, 1993 (Statistic of Indonesian Environment, 1993), Jakarta, Indonesia*
5. *Richardson G. P. and Alexander L. III, 1983, Introduction to System Dynamics Modelling With Dynamo, MIT Press, Cambridge, Massachussets, USA*
6. *Sosrodarsono, S., Takeda, K., 1993, Hidrologi untuk Pengairan (Hydrology for Irrigation), Pradnya Paramita, Jakarta, Indonesia*
7. *Suparmoko, 1994, Ekonomi Sumber Daya Alam dan Lingkungan (Economic Resources and Environment), BPFE, Yogyakarta, Indonesia*