# CALIBRATING A WATER YIELD MODEL FOR THE DEVELOPMENT OF HYDROLOGIC PARAMETERS OF UNGAGED SMALL WATERSHEDS IN MOUNTAINOUS TERRAIN OF TROPICAL MONSOON REGION

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## INTRODUCTION

In order to ameliorate the environmental degradation in Indonesia, particularly in Java, the Indonesian government has implemented many rehabilitation programmes related to watershed management for conserving water resources, such as reforestation, soil conservation measures, etc, but the rate of degradation still exceeds that of the success of the programmes. An innovative hydrological calculation is still needed for predicting water yields in a simple way.

This report deals with predicting water yields from ungaged watersheds using a water balance approach. A five parameters' water yield model developed by Van Der Beken and Byloos (1977) was used to study water yield from eight small watersheds in the mountainous terrain of the tropical monsoon region, Central Java, Indonesia.

## THE MODEL

Rainfall and evapotranspiration are the model's inputs. These inputs are used by a series of equations that relate to the different hydrologic processes, such as infiltration, evapotranspiration, surface runoff, percolation, and groundwater return.

Before this model can predict water yield from a specific watershed, five parameters must be determined. They are:

*a1* = evapotranspiration (*a1* >= 0),
*a2* = base flow (0 <= *a2* <= 1),
*a3* = surface run-off (0<= *a3*<= 1),
*a4* = percolation rate (*a4* >=0), and
*a5* = channel seepage (*a5* <= 0).

These parameters cannot be directly measured for a particular watershed. For gaged watersheds, the optimum values for these parameters are obtained by minimising the sum of the squares of the differences between observed and simulated monthly runoff. Trial and error was used for optimising the parameters. For watersheds with no runoff records, alternate methods for estimating the five model parameters had to be found. In this study an attempt was made to relate the five model parameters to measurable watershed characteristics.

The objective of this study was to develop a reliable method for estimating the five parameters of the water yield model for small ungaged watersheds in the mountainous terrain of the tropical monsoon region. Equations for predicting the parameters were developed on one set of gaged watersheds and tested on a second independent set of ungaged watersheds. This testing gave a reliable check on the accuracy of the prediction.

Other studies on the relationships between the parameters of mathematical hydrological models and the watershed characteristics have been carried out. Five small-gaged watersheds were used for optimising the parameters model in this study. Optimum parameters were regressed on the watershed characteristics. They are the average slope of the watershed (S), gradient of the main river (G), percentage of total area of the watershed to forest area (AF), percentage of total area of the watershed to rice field area (AR), percentage of total area of the watershed to rainfed or upland area (AU), and percentage of total area of the watershed to settlements area (AS). The relationships were tested by comparing observed and simulated runoff records from three watersheds that were not contained in the five calibrated watersheds. Three years of monthly data were used in this study.

## RESULTS

Table 1 shows the characteristics of the watershed studied. The first group of five-gaged watersheds, denoted as calibration watersheds, was used to develop the regression equations for predicting the model's parameters. The

other three ungaged watersheds were retained to be used in testing the calibrated model. The result of the regression analysis was a prediction equation for each of the five model parameters. These equations are as follow.

a1 = - 0.0262 - 0.0194 S - 0.0055 G - 0.0229 AF - 0.0090 AR - 0.1110 AU - 0.0023 AS

a2 = - 0.5637 - 0.3589 S - 0.1852 G - 0.2966 AF - 0.6701 AR - 0.3445 AU - 0.0672 AS

a3 = + 1.4244 - 0.3715 S - 0.3572 G - 1.0807 AF + 0.2723 AR - 1.3867 AU - 0.9663 AS

a4 = - 1.7086 - 0.4100 S + 0.5377 G + 1.7489 AF + 1.7931 AR + 1.7520 AU + 2.0823 AS

a5 = + 0.7666 - 3.1007 S + 5.6446 G + 5.1660 AF + 9.3965 AR + 3.4369 AU + 11.5243 AS

Using the equations, a typical result of the model's performance presented by comparing observation and simulated water yield for the Duren watershed is shown in Figure 1. Optimum parameter results together with evaluation of the model on the basis of four statistical measures is presented in Table 2.

## CONCLUSION

Optimum parameters for a five parameter monthly water yield model has been obtained on five small gaged watersheds in the mountainous terrain of the tropical monsoon region, Central Java, Indonesia. These optimum parameters were then regressed on watershed characteristics. Prediction equations were derived for each model parameter. These equation were used to calculate the model parameters for the other three watersheds from the watershed characteristics. By using these calculated parameters, simulations of runoff in these ungaged watersheds were made. Comparisons were made between the simulated and observed runoff. Graphical and statistical indicators were used to identify the accuracy of the model's performance. The method of developing the parameter prediction equations should not be used on watersheds greater than 3,500ha in area.

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## REFERENCE

Van Der Beken, A. and Byloos, J., 1977. 'A Monthly Water Balance Model Including Deep Infiltration and Canal Losses'. In *Hydrologycal Sciences Bulletin,* 22(3) (pp341-51).

Table 1. Watersheds Studied

| No | Watershed | A (ha) | S (%) | G (%) | AR (%) | AF (%) | AU (%) | AS (%) |
|---|---|---|---|---|---|---|---|---|
| 1. | Duren | 163 | 24 | 6.3 | 13 | 28 | 37 | 22 |
| 2. | Wader | 202 | 40 | 19.0 | 17 | 47 | 23 | 13 |
| 3. | Wungu | 203 | 46 | 18.5 | 27 | 6 | 63 | 4 |
| 4. | Plawatan | 261 | 24 | 5.0 | 4 | 40 | 46 | 10 |
| 5. | Padas | 3485 | 34 | 0.6 | 13 | 12 | 59 | 16 |
| 6. | Ngunut I | 596 | 18 | 3.0 | 21 | 7 | 27 | 27 |
| 7. | Ngunut II | 186 | 9 | 7.0 | 12 | 0 | 46 | 42 |
| 8. | Tapan | 184 | 41 | 12.2 | 5 | 59 | 30 | 5 |

Notes: A : watershed area; S : average slope of watershed; G : gradient of main river; AF : percentage of total area of the watershed to forest area; AR: percentage of total area of the watershed to rice field area; AJ: percentage of total area of the watershed to rainfed area; AS : percentage of total area of the watershed to settlements area

Table 2. Parameter Values and Statistical Measures for Each Watersheds Studied

| No | Watershed | a1 | a2 | a3 | a4 | a5 | SE | CD | CC | MB |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | Duren | 0.006 | 0.30 | 0.10 | 0.40 | 10 | 0.82 | 0.73 | 0.88 | 0.15 |
| 2. | Wader | 0.002 | 0.15 | 0.33 | 0.10 | 7 | 0.96 | 0.76 | 0.88 | 0.09 |
| 3. | Wungu | 0.005 | 0.05 | 0.33 | 0.40 | 6 | 1.78 | 0.64 | 0.83 | 0.06 |
| 4. | Plawatan | 0.005 | 0.30 | 0.33 | 0.06 | 6 | 1.45 | 0.86 | 0.93 | 0.03 |
| 5. | Padas | 0.010 | 0.03 | 0.08 | 0.01 | 5 | 3.60 | 0.72 | 0.87 | 0.05 |
| 6. | Ngunut I | 0.001 | 0.06 | 0.08 | 0.01 | 6 | 0.13 | 0.55 | 0.79 | 0.12 |
| 7. | Ngunut II | 0.001 | 0.08 | 0.01 | 0.90 | 10 | 0.39 | 0.60 | 0.86 | 0.18 |
| 8. | Tapan | 0.001 | 0.065 | 0.04 | 0.001 | 5 | 0.33 | 0.57 | 0.82 | 0.03 |

Notes: SE : standard error; CD : Coefficient determination; CC : coefficient correlation; MB : mass balance

Fig. 1. Typical results of simulated and recorded runoff at the Duren watershed
(a) Time-series diagram, (b) Scatter diagram