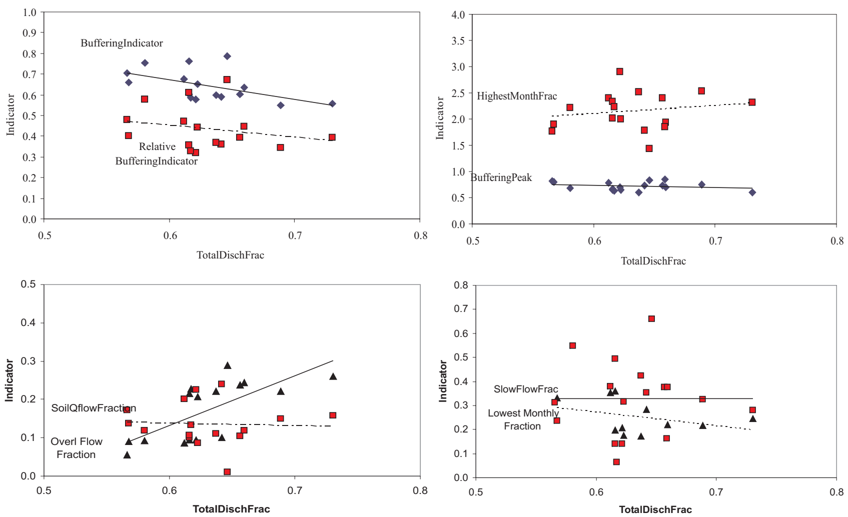
| Indicators | Observed in 30 years | | | Simulated for 30 years | | |
|---|---|---|---|---|---|---|
| | Min | Average | Max | Min | Average | Max |
| Total discharge fraction (water yield per unit rainfall) | 0.1 | 0.6 | 0.8 | 0.6 | 0.6 | 0.7 |
| Buffering indicator (1 - peak flows relative to peak rainfall | 0.5 | 0.7 | 0.9 | 0.5 | 0.6 | 0.8 |
| Relative buffering indicator | 0 | 0.4 | 0.6 | 0.3 | 0.4 | 0.7 |
| Buffering peak events | 0.6 | 0.7 | 0.8 | 0.6 | 0.7 | 0.8 |
| Highest monthly discharge relative to mean rainfall | 1.6 | 2.1 | 4.7 | 1.4 | 2.2 | 2.9 |
| Overland flow fraction | - | - | - | 0.1 | 0.2 | 0.3 |
| Soil quick-flow fraction | - | - | - | 0.0 | 0.1 | 0.2 |
| Slow flow fraction | - | - | - | 0.1 | 0.3 | 0.4 |
| Lowest monthly discharge relative to mean rainfall | - | - | - | 0.1 | 0.3 | 0.1 |




Overall, the model results show that details of the rainfall regime dominate the river flow results, but land cover change and soil compaction do modify the results. The model can be used to explore a wider set of land use scenarios and impacts of climate change.

## How to get the model?

GenRIver was developed in the Stella modelling platform. A free downloadable version of Stella (demo version) is available at http://www.iseesystems.com/. GenRiver model is available on the Internet and it can be downloaded freely from http://www.worldagroforestry.org/sea/Products/AFModels/GenRiver/genriver.htm.



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**Contacts:**
TUL-SEA Project
WORLD AGROFORESTRY CENTRE
Southeast Asia Regional Office
Jl CIFOR, Situ Gede, Sindang Barang, Bogor 16115
PO Box 161 Bogor 16001, Indonesia
Tel: +62 251 8625415/ Fax: +62 251 8625416
E-mail: icraf-indonesia@cgiar.org
http://www.worldagroforestrycentre.org/sea/



**Credits:**
Authors: Ni'matul Khasanah and Meine van Noordwijk
Photos: Rudy Harto Widodo
Design & Layout: Vidya Fitrian and Diah Wulandari


*TUL-SEA: A negotiation support toolbox for Integrated Natural Resource Management*

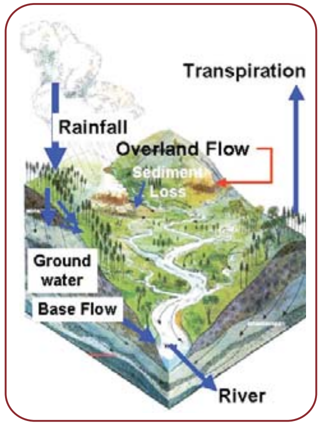
# GENeric Model of RIVER Flow (GEN-RIVER)

A landscape level model

***Trees in Multi-Use Landscape in Southeast Asia (TUL-SEA)***
*A negotiation support toolbox for Integrated Natural Resource Management*

## Why Model River Flow?

Land cover change can significantly affect watershed functions through changes in the fraction of rainfall that reaches the ground, the subsequent pathways of water flow over and through the soil and the rate of water use by plants. Simple characteristics of the vegetation (monthly pattern of leaf biomass, influencing canopy interception and transpiration, and ability to extracts water from deeper soil layers) and soil (especially compaction of the macropores in the soil that store water between 'saturation' and 'field capacity') can probably explain a major part of the impacts on river flow. Empirical assessment of the dynamics of water flows as a function of land cover change and soil properties takes time and resources, and needs to take temporal and spatial variation of rainfall into account. A model based on 'first principles' that integrates land cover change and change in soil properties as driving factors of changes in river flow can be used as a tool to explore scenario's of land use change, if it passes a 'validation' test against observed data.




## GenRiver Model

GenRiver is a generic river model on river flow. As is common in hydrology, it starts the accounting with rainfall or precipitation (P) and traces the subsequent flows and storage in the landscape, that can lead to either evapotranspiration (E), river flow (Q) or change in storage ( $\triangle$ S ):

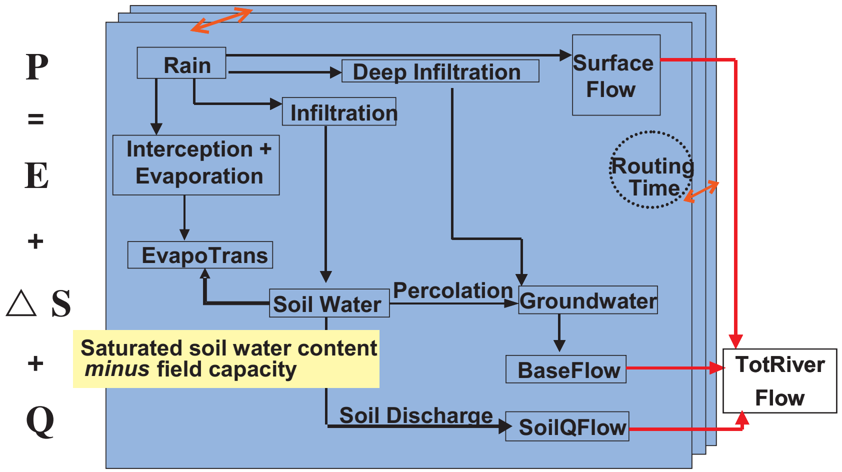
$$P = Q + E + \triangle S \quad \text{......................................(1)}$$

Models differ in the relations between the different terms of the balance equation and in the way they account for the 'slow flows', that derive from water that infiltrates into the soil but can take a range of pathways, with various residence times, to reach the streams and rivers, depending on land form, geology and extractions along the way.

The core of the GenRiver model is a 'patch' level representation of a daily water balance, driven by local rainfall and modified by the land cover and land cover change and soil properties of the patch. The patch can contribute to three types of stream flow: surface-quick flow on the day of the rainfall event, soil-quick flow on the next day and base flow, via the gradual release of groundwater.

A river is treated as a summation of streams, each originating in a sub-catchment with its own daily rainfall, yearly land cover fractions and constant total area and distance to the river outflow (or measurement) point. Interactions between streams in their contribution to the river are considered to be negligible (i.e. there is no 'backflow' problem). Spatial patterns in daily rainfall events are translated into average daily rainfall in each sub-catchment. The sub-catchment model represents interception, infiltration into soil, rapid percolation into subsoil, surface flow of water and rapid lateral subsurface flow into streams with parameters that can vary between land cover classes.

**Subcatchments can differ in (timing of) rainfall, vegetation, inherent soils, soil compaction and routing time for stream flow**




The model was first implemented in Stella accompanied by an excel file to store input parameters; a NetLogo version is also available.

# Example of Model Application

We used GenRiver to assess the importance of rainfall variation ('climate change') and land cover change ('deforestation') in the Way Besai watershed in Sumberjaya, West Lampung (Sumatra, Indonesia). Sumberjaya is situated between 4° 56' 6" and 5° 11' 25" South and 104° 17' 52" and 103° 33' 51" East. The elevation ranges between 720 m and 1831 m above sea level. The area of Sumberjaya is about 415 km2.

Model simulations used rainfall data from August 1976 - May 2007 with annual rainfall of 2500  3500 mm per year. Eight landcover types were distinguished:

| | Relative soil bulk density[1] | Potential interception storage[2] | Relative drought threshold[3] | Land Cover Change (ALL subcatchments) | | | |
|---|---|---|---|---|---|---|---|
| ***Landcover*** | **BD/BDref** | **mm** | | **1976** | **1986** | **2000** | **2007** |
| *Forest* | 0.7 | 4 | 0.45 | 0.43 | 0.18 | 0.11 | 0.1 |
| *Simple shade* | 1 | 2 | 0.55 | 0 | 0 | 0.06 | 0.13 |
| *Multistrata* | 1 | 3 | 0.5 | 0.12 | 0.36 | 0.44 | 0.48 |
| *Shrub and grassland* | 1.07 | 3 | 0.6 | 0.27 | 0.13 | 0.14 | 0.04 |
| *Holticulture* | 1.07 | 1 | 0.7 | 0.01 | 0.01 | 0.01 | 0.03 |
| *Sun coffee* | 1.08 | 1 | 0.55 | 0.16 | 0.19 | 0.2 | 0.09 |
| *Ricefield* | 1.1 | 1 | 0.8 | 0.004 | 0.08 | 0.01 | 0.1 |
| *Settlement* | 1.3 | 0.05 | 0.1 | 0.01 | 0.03 | 0.02 | 0.03 |

1. Increase in BD/BDref reflects soil compaction and shifts 'soilquickflow' to 'overland flow'
2. The amount of water stored on the canopy that can directly evaporate
3. lower values imply that the vegetation is less sensitive to drought

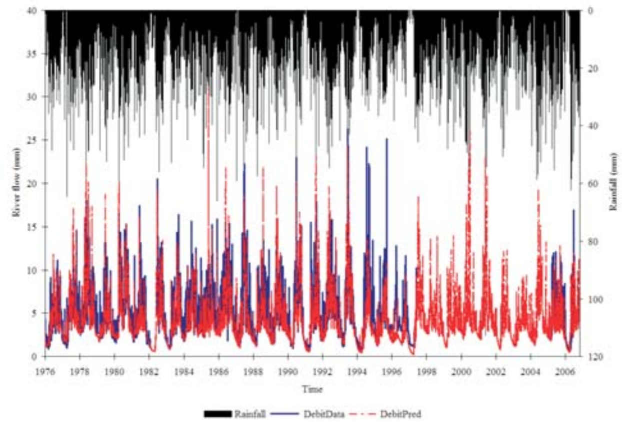


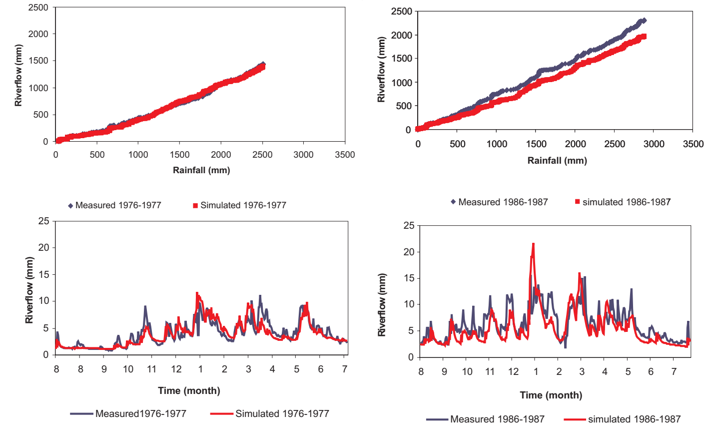


The major soils are inceptisols (Dystropepts, Dystrandepts and Humitropepts) with some entisols (Troporthent), with differences in soil texture and water holding capacity.

*Result  River flow model performance*

The model simulation could capture most of the observed pattern across 30-year period. Overall there was a 'moderately good fit' of model estimates with field measurement data; part of the rainfall and river flow field data are probably less reliable. Also, spatial variability of rainfall over the catchment was not fully represented in the field data.




The watershed function of the Way Besai catchment can be assessed using criteria and indicator of water transmission (total water yield per unit rainfall), buffering capacity (peak flows relative to peak rainfall events) and gradual release of ground (dry season flow). Simulations and observations for these indicators match sufficiently to use the model for further scenario studies.

The main source of year-to-year variation in river flow is the rainfall, with wetter years leading to a higher total discharge fraction. The main effect of land cover change was an increase in the discharge fraction as well. Land cover change and associated soil compaction also increased the overland flow fraction, but this has only a small effect on the daily hydro-graph. Indicators of gradual water release (slow flow and soil quick flow fractions, and lowest monthly river flow) tended to decrease over the years, along with more pronounced dry seasons in the 1990's. Further analysis suggests that this was in response to El Nino and Indian Ocean Dipole anomaly years. The buffering capacity (buffering indicator, relative buffering indicator and buffering of peak events) was relatively low in the 1990's but increased in recent years.