Title of project: Discharge regimes, morphometry and tides in the Mahakam delta channel network

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Sub-title:
Rainfall-runoff modelling in large tropical poorly gauged basin–The Mahakam River, Kalimantan

Institute: Wageningen UR

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Results

In order to accomplish the research objective, data collection has been carried out with collaboration with the Indonesian counterpart since January 2008 and will be completed in September 2009. Tables 1 and 2 summarize the data collection during this period.

Table 1. Collected data during field campaign

Parameter	Measurement type/tool	Location	Resolution/period
Surface water level	Pressure sensor	River Mahakam (at Muara Kaman, Pela, Muara Muntai, Penyinggahan), lakes (Semayang, Melintang, Jempang)	15 minutes, 2008-2009
Groundwater level	Pressure sensor	Teluk Tuk, Penyinggahan	15 minutes, 2008-2009
Discharge	ADCP	Samarinda, Melak	Hourly, 2008-2009
Rainfall	Tipping bucket raingauge	Melak, Penyinggahan, Teluk Tuk, Muara Kaman	Hourly, 2008-2009
Water conductivity	Salinity sensor	Melak, Penyinggahan, Belayan	Hourly, 2008-2009
Bathymetry	Echosounder	Mahakam from Melak downstream to delta area	Spatial res: 250-350 m

Table 2. Available data from related institutions.

Parameter	Measurement type/tool	Location	Resolution/period
Discharge	Water stage-discharge	Mahakam River at Melak Belayan River at Tabang K. Kepala at M. Ancalong Mahakam at Kotabangun	Daily, 2001-2005 Daily, 1998 (a half year) Daily, 1998, 2004 Daily, 1993-2004
Rainfall, temperature, relative humidity, wind speed	Automatic weather station	Kotabangun	3-hourly, daily 2000-2007
Rainfall	Raingauge	Melak, Penyinggahan, Kotabangun, Muara Kaman, Sebulu, Tenggarong, Samarinda, Telukdalam	Daily, 1993-2004 (with some missing data)
Rainfall estimates	TRMM satellite	worldwide 0.25˚grid between 50˚N-50˚S latitude	3-hourly, daily, monthly, 1998-present
Flood inundation extent	ALOS-PALSAR imagery	Mahakam region	46 days, 2007-2008
Digital elevation model	SRTM-NASA	Kalimantan region	Spatial res: 90 m
Physiographic condition	Maps (topography, geology, soil)	East Kalimantan region	Varied type

Water level

Surface water level measurements using pressure sensors have been settled in the locations along the river (Penyinggahan, Muara Muntai, Kotabangun, Muara Kaman, Tenggarong), river-lake channels (in Jantur for Lake Jempang and Pela for Lake Semayang-Melintang), and main lakes (Jempang, Semayang, Melintang). The instruments are set to record water level in every 15 minutes period. Water levels in the upstream stations are highly fluctuating in response to rainfall in the catchment, while more downstream they are also influenced by tidal wave. Tidal effect on water level is observed in most of the measuring period at least until the River Mahakam-Lake Semayang junction in Kotabangun.

Groundwater level measurements using pressure sensors are carried out in two neighboring peat land locations. The first location is a forest covered peat land in Teluk Tuk (near Lake Semayang) and the second one is a reed-vegetated peat land in Penyinggahan where forest vegetations had been vanished due to previously occurred forest fire. The location in Penyinggahan is close to Mahakam river, wet most of the time and completely inundated during high water period. Water level in Penyinggahan peat land is less variable than the one in Teluk Tuk in response to high rainfall. It keeps increasing with high rainfall until the peak level, as it is part of river floodplain and also due to water saturated peat soil, and decreasing with the same trend as the river water level. Different pattern is observed for the Teluk Tuk water level data, which shows the dynamics of groundwater level and hydrological functioning of the forest-vegetated peat land.

Rainfall

Rainfall measurements have been set in four locations in the middle Mahakam area (Melak, Penyinggahan, Teluk Tuk, and Muara Kaman) using tipping bucket rain gauges with automatic recorders to obtain rainfall pattern of the study area. However, a lot more points of measurement is required to cover spatial rainfall variability in the catchment, which is technically and financially difficult to implement. Rainfall estimation based on remote sensing techniques is a promising alternative data source in a poorly-gauged catchment like the Mahakam. TRMM multi satellite precipitation analysis (TMPA) rainfall estimates products (3B42RT - Real Time 3-hourly, 3B42V6 3-hourly, 3B42V6 daily derived, and 3B43V6 monthly) have been evaluated by comparing the 0.25˚ resolution TRMM algorithm rainfall estimates with the ground rainfall measurement record. Daily rainfall estimates are generally poorly correlated with the ground rainfall record, but in the longer period, e.g. monthly, they correlate better. This is related to the difference in the nature of area averaged TRMM rainfall estimates and point rainfall measurement of the rain gauge besides the accuracy issue of the satellite rainfall estimation.

Despite the uncertainty involved in the TRMM rainfall estimates, it is considered the best available data source so far in terms of coverage especially for the upstream part of the catchment, where there is no ground rainfall measurement. It also provides spatial and temporal distribution of rainfall in the catchment. Fig. 1 shows the distribution of rainfall around the study area for the year 2008 with a relatively higher rainfall in the sub-catchment upstream of Melak compared to those of the middle and lower Mahakam region.

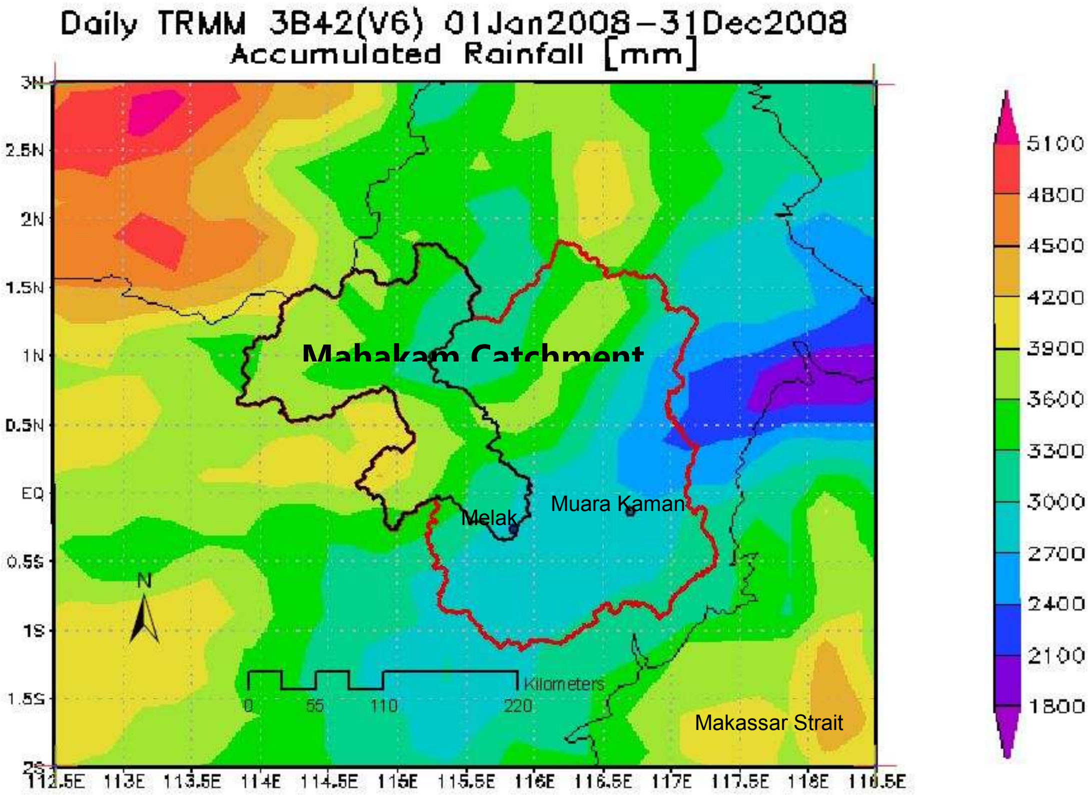

Fig 1. Spatial distribution of rainfall in the Mahakam catchment based on TRMM rainfall estimates.

Evapotraspiration

Reference evapotranspiration for Kotabangun was calculated based on automatic weather station data using Penman–Monteith formula:

$$ET_{P-M} = \frac{C}{L}\frac{sR_N + c_p\rho_a(e_a - e_d)/r_a}{s + \gamma(1 + r_c/r_a)}$$

where (all constants are referred to values taken by FAO):

ET_{P-M} potential evaporation of grass [mm.d^{-1}]

C constant to convert units from kg.m^{-2}.s^{-1} to mm. d^{-1} (C=86400)

R_N net radiation at earth's surface [W.m^{-2}]

L latent heat of vaporation (*L*=2.45*106 J.kg^{-1})

s slope of the temperature-saturation vapour pressure curve (kPa.K^{-1})

c_p specific heat of air at constant pressure (c_p =1004.6 J.kg^{-1}.K^{-1})

ρ_a density of air (ρ_a =1.2047 kg.m^{-3} at sea level)

e_d actual vapour pressure of the air at 2 m height [kPa],

e_a saturation vapour pressure for the air temperature at 2 m height [kPa]

γ psychrometric constant (γ =0.067 kPa.K^{-1} at sea level)

r_a aerodynamic resistance [s.m^{-1}]

r_c crop resistance [s.m^{-1}] (r_c =70 s.m^{-1} for grass)

The aerodynamic resistance r_a is a function of wind speed observed at a height of 2 m over grass, U_2 (m.s^{-1})

$r_a = \frac{208}{U_2}$; e_a and *s* are obtained from $e_a = 0.6108e^{\frac{17.27T_a}{273.3+T_a}}$; $s = \frac{4098e_a}{(273.3+T_a)^2}$

where T_a is the 24 hour mean temperature of the air [ºC]

The actual or dewpoint vapour pressure e_d is calculated from relative humidity *RH*,

$$e_d = e_a \frac{RH}{100}$$

The net radiation R_N is calculated as the incoming short wave radiation at the earth's surface (or global radiation) R_s minus the fraction *r* that is reflected and minus the net outgoing long wave radiation R_{nL}

$$R_N = (1 - r)R_s - R_{nL}$$

where

r reflection coefficient (*r*=0.23 for grass)

$$R_s = (0.20 + 0.60n / N)R_A$$

n/N fraction of sunshine per day

R_A radiation received at the outer limit of the atmosphere are read for a given date and latitude (de Laat, 1992).

Calculated reference evapotranspiration at Kotabangun BPTP station for year 2004 and 2005 are 1082 and 1077 mm respectively (range: 2.1 - 3.6 mm/day). Evapotranspiration estimation with Makkink simplified equation, which is based only on radiation and temperature data only, is also carried out for comparison with the following formula:

$$ET_{Makkink} = CC_M \frac{s}{s+\gamma} \frac{R_s}{L}$$

$ET_{Makkink}$ for 2004 and 2005 are 1086 and 1074 mm respectively. These values fall within the ET range of 885-1285 for north Borneo estimated by Bruijnzeel (1990) as cited by Dykes (1997).

Discharge

Fixed side looking horizontal acoustic Doppler current profiler (H-ADCP) are installed in two locations, one in Melak and the other one in Samarinda for measuring discharge. Boat-mounted ADCP transects in several water stage conditions had been carried out to calibrate this H-ADCP discharge measurements. Field measurement and discharge data processing is currently in progress.

Preliminary runoff simulation for Melak using lumped HBV model with TRMM rainfall estimates and calculated evapotranspiration data input is carried out for water balance study and discharge prediction (fig. 2). This model is calibrated using discharge information obtained from local public work institution, which is based on the Hymos-Manning stage-discharge relation. The model will be recalibrated when the discharge estimate from ADCP measurement is available. The parameter set obtained from the calibration of the melak sub-catchment will be used to estimate discharge contribution of the Mahakam tributaries by means of sub-catchments rainfall-runoff modeling.