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Impacts of climate and land-use changes on the hydrological dynamics in the upper Citarum River basin based on the J2000 hydrological model

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Changes of land-use and climate will most likely result in changes of the hydrological dynamics in river basins. Such changes can be noticed in the upper Citarum River basin (UCB), Java Island, Indonesia. This basin covers 1821km^2 and is located in a hilly area of the backcountry of Jakarta. Between 2005 and 2009, the basin's forest cover has been reduced by 5.0%, residential areas grew around 8.2% expanding around the existing residential areas, and 3.9% of shrubland was converted into agricultural areas. From 1985 through 2009, the mean annual air temperature increased by 0.01˚C/year; whereas, precipitation slightly decreased by 6.8mm/year.

The process-oriented hydrological model JAMS/J2000 was adapted and implemented to assess the impact of land-use change and climate variability on the hydrological dynamics of this basin, including consideration of the temporal and spatial distributions. For this assessment, three scenarios based on realistic events were investigated; these consisted of the following (i) land-use changes in 2005 versus 2009; (ii) temperature increase from 1984 to 2009, while keeping a precipitation constant from year 1984; and (iii) variability of precipitation from 1984 to 2009, while keeping temperature constant from year 1984. The model-input conditions of land-use, precipitation, and temperature changes where applied individually, holding the other factors constant. Model simulations were conducted for the UCB. The J2000 model for the UCB was calibrated and validated using a split-sample approach. For model calibration and validation, fairly good objective functions were achieved: i.e. Nash-Sutcliffe efficiencies (E) by 0.79 and 0.76, log E of 0.89 and 0.84, coefficient of determination of 0.79 and 0.77, and a percent bias of -1.4% and -1.1%.

From the model-simulation results, it was concluded that the land-use changes resulted in a slight increase in stream discharge (4.6%) and a decrease of evaporation of 3.7%. The analysis of the different runoff components indicated that, in particular, the amount of overland flow was estimated to increase 7.9%, primarily because of the significant expansion of residential areas. The individual effects of precipitation and temperature changes on the hydrological dynamics was evaluated for four five-year periods (1989-1993, 1994-1998, 1999-2003, and 2004-2009) for comparison with conditions for the first five-year period (1984-1988). The effect of a temperature increase from 1989 to 2009 on stream discharge was small, resulting in a reduction of about 1%. The increase of precipitation from 1985 to 1999 was affecting stream discharge by a small increase (2%).

Through this application of the J2000, which proved to be an appropriate tool to assess environmental (land-use and climate) changes on the basin's hydrological dynamics, we could show that in the Indonesian test basin the observed change in land-use change might have a greater impact on hydrological dynamics than the impact of climate change. For future study, it is recommended to assess hydrological changes under the projected future climate and land-use conditions. Coupling effects of climate and land-use changes should be considered and assessed individually when quantifying the resultant hydrological changes estimated by the model.