Development of an integrated model INDOCLIM for understanding the future state of a river basin

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WATER PROBLEM

Hydrology of a river basin is affected by changes in land use (Taniguchi & Bari, 1997; Lørup *et al.*, 1998) and climate (Arnell & Liu, 2001; IPCC, 2007). Land-use change affects hydrological parameters such as water infiltration, evapotranspiration and runoff. Climate change affects the amount of precipitation and temperature for evaporation. These two components, land use and climate, can work together to alter the quantity and variability of river flows.

This change in the quantity and variability of the river flows could be in the form of more intense seasonal flood and drought. Population increase and urbanization not only drives the land-use change, but could also increase hydrology pressures as a result of a higher demand for clean water and increased pollutant load. Improper water management and water treatment, including pollution control, could downgrade the quality of the river flows.

INTEGRATED MODEL, INDOCLIM

An integrated model is necessary to understand the multiple effects of changes in climate and land-use on the hydrology of a river basin in relation to land-use and water-use planning and management for sustainable development.

INDOCLIM is an integrated model that has been developed to allow hydrologists, planners and general users to explore the relative effects of these changes on the quantity and variability of river flows (Santoso, 2003). The model is user-oriented, and is basically designed for sensitivity analysis to answer "what could happen if" questions.

The basic structure of the integrated model INDOCLIM consists of three main components: land use, climate and hydrology. The land-use component is used to generate land-use change patterns based on defined policy scenarios (business-as-usual, ecological concern, pro-industrialisation and pro-agriculture). The land-use patterns for each scenario were created in time series using a GIS, based on the cellular automata principle. The climate component is used to generate time dependent climate scenarios based on global temperature changes under IPCC SRES greenhouse gas emission scenarios (IPCC, 2000) and downscaled GCM patterns. The land-use patterns are translated into a set of hydrological parameters which are then, together with the climate variables, transferred to the hydrology component for monthly discharge calculation on a cell-by-cell basis. The calculation uses a water balance method. The runoff is totalled from all cells in the basin area (Santoso & Warrick, 2003).

The structure of INDOCLIM is open. The land-use patterns and climate scenarios are made off-line in the form of library files. The model accesses these library files when the hydrology component requires them. This open structure allows new time-series or non-time series land-use patterns to easily link with the main model components. Similarly, a new climate scenario ensemble can easily be added into the model, or can replace the existing ensembles. The open structure of the model also allows other components to be integrated into the system. For example, a pollutant load model can be integrated into the system to simulate water quality change as a result of changes in population and land use.

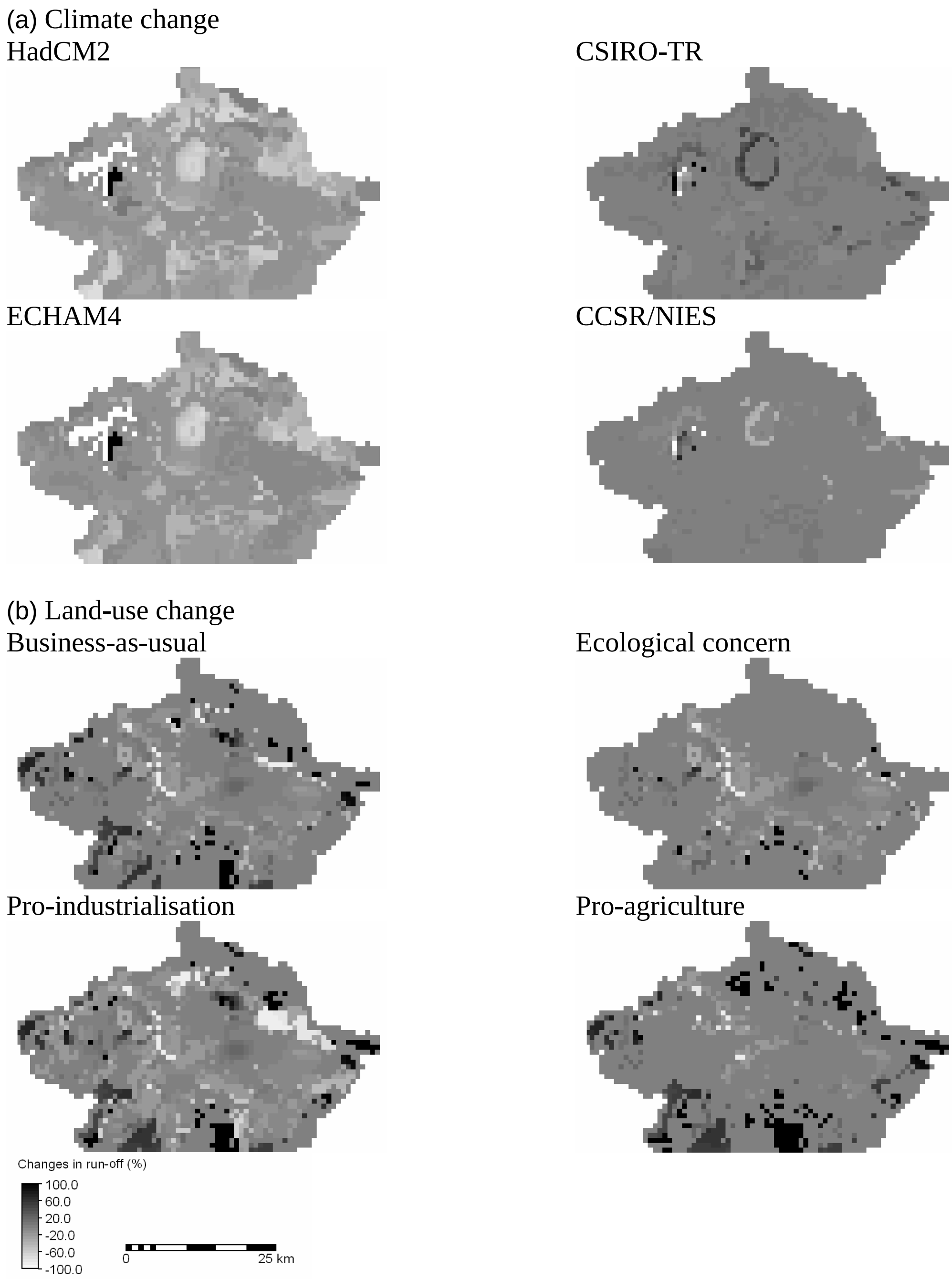

Fig. 1 The effect of climate change (a) and land-use change (b) on the spatial runoff for the year 2050. The climate change emission scenario was set to A2 for four different circulation models. The land-use change patterns were generated based on four policy oriented scenarios (Santoso & Warrick, 2003).

EXAMPLES OF MODEL APPLICATION

The primary purpose of the model is to examine relative effects of changes in land use and climate on the streamflow (Santoso & Warrick, 2003). However, extended applications of the model are possible, for example for an assessment of infiltration degradation level. Below are three examples of model application development which were applied in the Upper Citarum River basin, West Java, Indonesia.

Effects of climate change and land-use change on spatial variation of runoff The model shows that both land-use change and climate change have impacts on the annual discharge. By the end of the 21st century, climate change has a greater possible impact on the annual yield and on monthly discharge variations than the land-use change. Superimposed effects of land-use change and climate change can exacerbate or reduce the effects. The land-use change has a more significant impact on local scale variation than the climate change (Fig. 1). The findings suggest that land use management, as part of an integrated water resource management, is relevant (Santoso & Warrick, 2003).

Effects of climate change and land-use change on pollutant concentration The concentration of pollutant depends on the pollutant load and the amount of water to dilute. The amount of pollutant load depends on type and source of the pollutant. Therefore, they are dependent on land-use types, and in many cases, also population. With an added component of pollutant load, the integrated model can project the effects of climate change and land-use change on pollutant concentration. Figure 2 shows a projection of active nitrogen concentration in 2050. Model showed that agriculture land expansion could generate higher N pollutant concentration. The model also showed spatial variation in pollutant concentration that could guide planners to identify where the anticipation measures should take place.

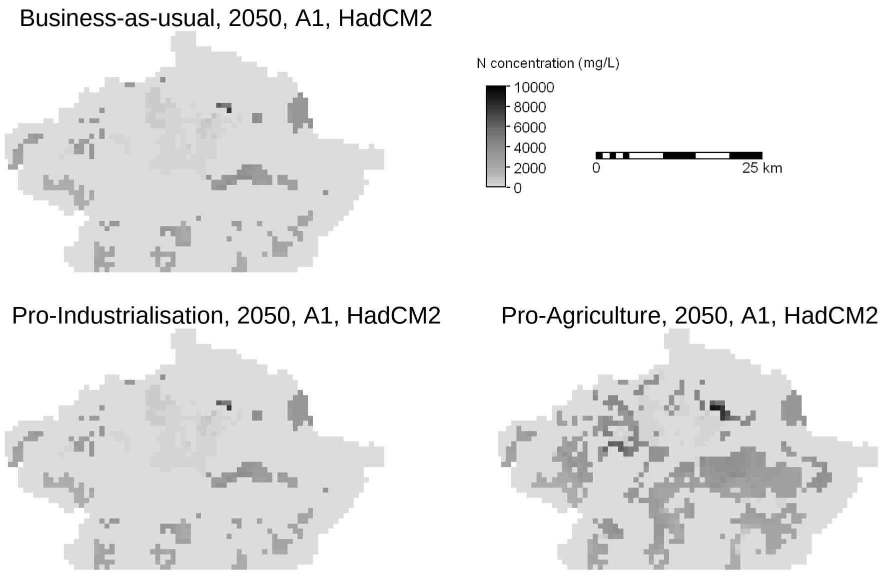

Fig. 2 Active nitrogen concentration pattern (mg/L) for three land-use change scenarios under a climate change influence in 2050. The model used A1 emission scenario and HadCM2 circulation model.

Infiltration degradation level Geology, soil type, land use and precipitation distribution are parameters that determine water infiltration. The difference between the current existing infiltration value and the infiltration value of the natural land use (tropical forest) gives the change in infiltration that indicates the level of infiltration degradation (Fig. 3). The model identified where the infiltration had been degraded most and where the rehabilitation should focus.

KEY LESSONS

Climate change and land-use change are the pressures in future water management. An integrated model such as INDOCLIM can help to explore the possible future states of a river basin under these pressures, which is useful for water use planning and management in relation to sustainable development. An open structure of the model has been found useful for further hydrological analysis, which is useful, for example, for basin rehabilitation planning.

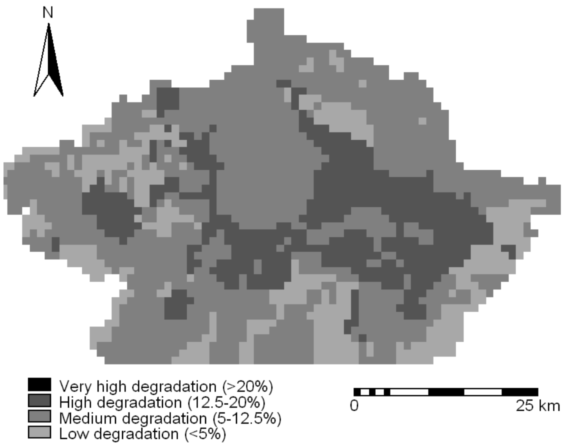

Fig. 3 Infiltration degradation level of the Upper Citarum River basin.

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