STREAM: a spatial tool for analyses in river basins

Jeroen Aerts and Hans de Moel *(IVM, Free University, the Netherlands)*

What is STREAM

STREAM (Spatial Tools for River basin Environmental Analysis and Management) is a GIS-based water balance model, covering an entire river basin including the coastal zone. STREAM is a raster based hydrological rainfall-runoff model for Windows computers. The model provides a user-friendly interface, uses an easy-to-learn script language, and can be used in a Decision Support System (DSS). STREAM was developed in response to the specific demand for models that could be coupled to other models. It allows the input of free of charge, spatial data, from GIS databases and satellite observations. It is easy to use, integrates the water and land components of river basins and land uses. It is therefore a unique tool for integrated coastal zone management.

The model simulates impacts of both climate change and land use change on river discharges and soil moisture availability. The model simulates human activities in the river basin, such as deforestation or reservoir dam construction. STREAM has been used in a variety of catchments worldwide, in combination with climate change scenarios, developed by the Intergovernmental Panel on Climate Change (IPCC). It is used in small river basins and at a global level, modeling the past, present and future situation, as well as over a geological timeframe.

Some technical information

The model is based on a raster GIS calculating the water balance for each grid cell of the basin. The resolution of the model application depends on the size of the river basin and varies between 300 x 300 m to 50 x 50 km. The larger the basin, the coarser is the minimum level of detail in the model. A digital elevation model (DEM) determines the direction of water flow. In STREAM, the water balance is calculated using temperature, rain, snowfall and snowmelt, soil water content and groundwater storage.

The spatial character of the model allows the analysis of water availability patterns and changes in these patterns caused by human activities (e.g. deforestation and drainage) and external influences such as climate change. The model uses so-called Blaise script-files in a Windows interface environment. Experienced modellers can easily modify these script files.

Input of STREAM

The simplicity of the model makes the model suitable for areas where data is difficult to obtain as most of the required data can be downloaded freely from the internet. Different equations for evapotranspiration are used such as the simple Thornthwaite & Mather (1957) equation. This equation uses temperature and precipitation as the major input variables. It calculates evaporation depending on land use and soil moisture. The model runs on a monthly basis generating direct runoff, delayed runoff, groundwater storage (shallow and deep), snow water equivalents and snow melt. The model uses the following five global GIS datasets as input:

- A digital elevation model (DEM);
- Total monthly precipitation;
- Average monthly temperature;
- Crop factors; and
- Maximum soil-water holding capacity.

The basin outlines and flow directions are based on a global digital elevation model at a resolution of 1x1 km Digital Elevation Map (GTOPO30, US Geological Survey 2004). Monthly climate data (precipitation and temperature) can be taken from the global CRU TS 2.0 dataset, which covers the entire globe for the period 1901-2000 on a 0.5 x 0.5 degree grid (Mitchell *et al.,* 2003). The water holding capacity is derived from the FAO soil map. Crop factors used for adjusting the reference

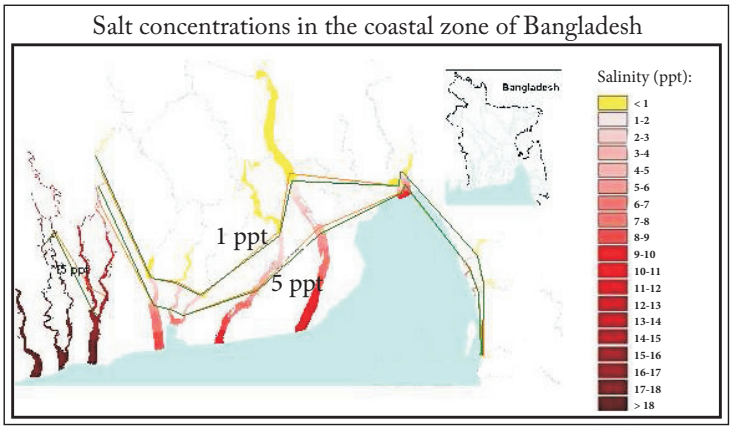

Figure 1: ***Example of STREAM output:*** *Salt concentrations (ppt= parts per thousand) in the waters of the coastal zone, Bangladesh.*

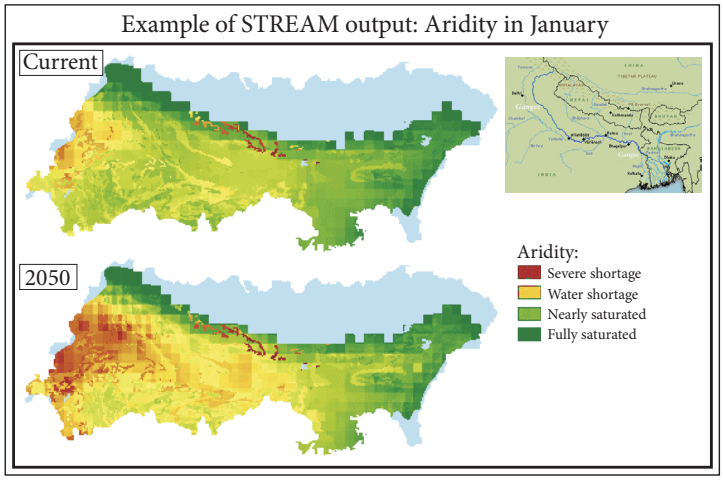

Figure 2: ***Example of STREAM output: Ganges, Brahamaputra, Meghna basin:*** *Aridity map for the month of January for the current situation,1960-1990, (Top) and under climate change, year 2050 (Bottom) The blue colour in the figure means that data was not available or that water is mainly stored as snow.*

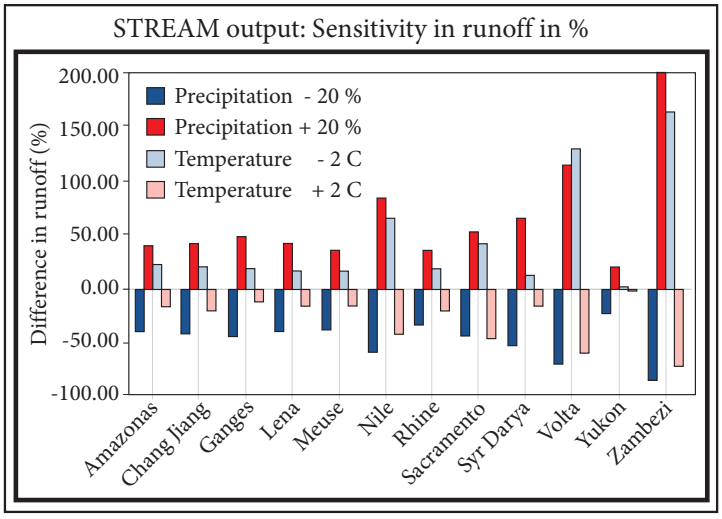

Figure 3: ***Example of STREAM output:*** *Sensitivity of the modeled runoff to changes in Temperature (+2 and –2º Celsius) and Precipitation (+20% and –20%) both relative to the present situation.*

potential evaporation, were adopted from FAO factors for different crop types (Doorenbos and Pruitt,1977).

STREAM applications worldwide

The STREAM model has been used in numerous projects. A flood modeling application of STREAM is set up in the central province of Vietnam - the TT Hue province: the Huong River Basin (Villegas 2004).

A number of STREAM projects around the world are highlighted in Figure 4. For more information on these projects, please see the publication section on the website of CWA – Cluster on Water and Adaptation.

Download the model

The model, as well as the manual and some additional files, can be downloaded from this website or ordered from the Institute for Environmental Studies (IVM). Researchers are encouraged to contact the authors to stay in touch on updates of the model. For questions or additional information, they can also be contacted. The website link is: http://www.adaptation.nl/ à STREAM

References

Aerts J.C.J.H., M. Kriek and M. Schepel, 1999: STREAM, spatial tools for river basins and environment and analysis of management options: 'Set up and requirements'. Physics and Chemistry of the Earth Part B, 24(6), 591-595.

Aerts, J.C.J.H., Hassan, A., Savenije, H.H.G., & Khan, M.F., 2000: Using GIS tools and rapid assessment techniques for determining salt intrusion: STREAM, a river basin management instrument. Physics and Chemistry of the Earth Part B, 25, 265-273.

Aerts, J.C.J.H., Renssen, H., Ward, P.J., de Moel, H., Odada, E., Bouwer, L.M. & Goosse, H., 2006: Sensitivity of global river discharges under Holocene and future climate conditions. Geophysical Research Letters, 33(19), L19401.

Bouwer, L.M., Aerts, J.C.J.H., Droogers, P. & Dolman, A.J., 2006: Detecting the long-term impacts from climate variability and increasing water consumption on runoff in the Krishna river basin (India). Hydrology and Earth System Sciences, 10(5), 703-713.

Bouwer, L.M., Aerts, J.C.J.H. & Misdorp, R., 2003: STREAM Report Vietnam 2003. Modeling the impact of land-use change on the runoff of the Perfume river basin (Vietnam) using STREAM. IVM-report (R-03/09), Institute for Environmental Studies, Amsterdam, 8 pp.

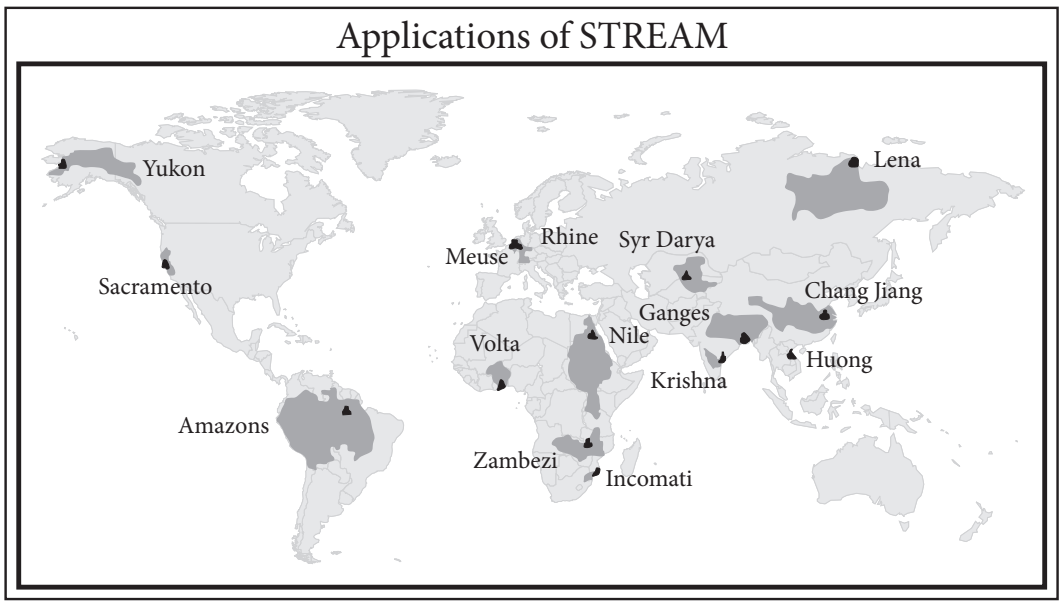

Figure 4: ***Location of the major STREAM application areas.***

Bouwer, L.M., Aerts, J.C.J.H. & Van Grol, E., 2003: STREAM Krishna Report 2003. The relative impact of climate variability and increasing water-use on the runoff of the Krishna River (India) during the past 100 years. IVM-report (R-03/10), Institute for Environmental Studies, Amsterdam, 21 pp.

Bouwer L.M., J Aerts, G M van de Coterlet, N van de Giesen, A Gieske and C Mannaerts, 2003: Evaluating Downscaling Methods for Preparing Global Circulation Model (GCM) Data for Hydrological Impact Modelling. In Climate Change in Contrasting River Basins: Adaptation Strategies for Water, Food and Environment (Eds J. Aerts and P. Droogers), CABI Press, London, UK.

Doorenbos, J., Pruitt, W.O., 1977: Crop water requirements. Irrigation and Drainage Paper No.24, (rev.) FAO, Rome, Italy, 144 pp.

Misdorp, R., Wulffraat, K., Aerts, J.C.J.H., 1999: Report of the International Workshop: "From river to coast" Chennai - India, December 1 and 2 1999 Work-document CZMC 2000.01.

Van Deursen, W.P.A. & Kwadijk, J.C.J. 1994: The impacts of climate change on the water balance of the Ganges-Brahmaputra and Yangtze Basin. Report RA94-160, Resource Analysis, Delft, The Netherlands.

Ward, P.J., Renssen, H., Aerts, J.C.J.H., van Balen, R.T. & Vandenberghe, J., 2008: Strong increases in flood frequency and discharge of the River Meuse over the late Holocene: impacts of long-term anthropogenic land use change and climate variability; Hydrology and Earth System Science 12, 159-175.

Ward, P.J., Aerts, J.C.J.H., de Moel, H., Renssen, H., 2007: Verification of a coupled climate-hydrological model against Holocene palaeo-hydrological records. Global and Planetary Change 57(3-4), 283-300.

Website and PDF reports

CWA- Cluster on Water and Adaptation: www.adaptation.nl

IVM - Institute for Environemnetal Studies, Free University Amsterdam: www.ivm.vu.nl

Mitchell et al., **2003**: Table of climate grids and derived data-sets: www.cru.uea.ac.uk/~timm/grid/table.html

Villegas, Piero, 2004: 'Flood modelling in the Perfume River Basin, Hue,Province Vietnam'; International Institute for Geo-information Science and Earth Observation, Enschede, the Netherlands: www.itc.nl/library/Papers_2004/msc/wrem/villegas.PDF