Hydrological Water Balance of Lake Tana, Ethiopia

[1]Yirgalem A. Chebud, [2]Assefa M. Melesse

[1]Department of Earth Sciences, Florida International University, USA

[2]Department of Environmental Studies, Florida International University, USA

Abstract

The level of Lake Tana fluctuates annually and seasonally following the patterns of changes in precipitation. In this study, a mass balance approach is used to estimate the hydrological balance of the lake. Water influx from five major rivers, subsurface inflow from the flood plains, precipitation, outflow from the lake constituting river discharge and evapotranspiration from the lake is analyzed on a monthly and annual basis. Spatial interpolation of precipitation using rain gage data was conducted using kriging. Outflow from the lake was identified as the evaporation from the lake surface as well as discharge at the outlet where the Blue Nile commences. Groundwater inflow is estimated using MODFLOW Software that showed an aligned flow pattern to the river channels. The groundwater outflow is considered negligible based on the secondary sources that confirmed absence of lake water geochemical mixing outside of the basin. Evaporation is estimated using Penman, Meyer's and Thornwaite's methods to compare the mass balance and energy balance approaches. Meteorological data, satellite images and temperature perturbation simulations from Global Historical Climate Network (GHCN) of NOAA are employed for estimation of evaporation input parameters. The difference of the inflow and out flow was taken as storage in depth and compared with the measured water level fluctuations. The study has shown that the monthly and annually calculated lake level replicates the observed values with RMSE value of 0.17m and 0.15m, respectively.

Key words: Lake Tana, Blue Nile River, water balance

Application of a physically based water balance model on four watersheds throughout the Upper Nile Basin in Ethiopia

.[1]Collick, Amy S. , [2]Easton, Zach M., [3] Adgo, Enyew, [4]Awulachew, Seleshi.B and [5]Steenhuis, Tammo S

[1]Assistant Professor Bahir Dar University,Bahir Dar, Ethiopia, asc38@cornell.edu

[2]Research Associate Cornell University, Ithaca, NY USA, zme2@cornell.edu

[3]Director Natural Resources, ARARI, Bahir Dar Ethiopia, enyewadgo@yahoo.com

[4]IWMI Regional Representative, Sub-regional Officer for Nile Basin & Eastern Africa, Addis Ababa, Ethiopia, s.bekele@cgiar.org

5Professor, Cornell University Ithaca NY USA, tss1@cornell.edu

ABSTRACT

Local hydrological knowledge is important because of the lack of long duration, continuous hydrological data at a small watershed scale and the extensive variability in rainfall and resulting runoff over the Ethiopian landscape. A better understanding of the local hydrological characteristics of different watersheds in the headwaters of the Nile River is of considerable importance because of the collective interest in the access to its water resources and the need to improve and augment development and management activities of these resources. A simple hydrological model for watersheds in varying locales at daily and weekly time scales was developed to gain insight into the hydrologic conditions of the larger Nile River basin. This model appears to be useful as a tool for planning watershed management and conservation activities. The water balance model was based on the Thornthwaite and Mather procedure, using rainfall and evaporation as major inputs, available water storage after the dry season and contributing area as partitioning factors within the watershed. Discharge data from three SRCP watersheds and one near Sekota were used for calibration of the storage coefficient. The Nash-Sutcliffe efficiencies along with other comparison statistics showed that model performed well compared to other water balances of the upper Nile Basin done with a monthly time step. The model was able to represent daily discharge values well. Despite the large

distance between the test watersheds, the input parameter values were remarkable similar. Good quality data, even for short durations, were key to the effective modeling of runoff in the highland watersheds.

Key words: variable source area, simulation model, water balance,

Flow Analysis and Characterization of Blue Nile River Basin System

[1]Melesse, A., [2]Abtew, W. and [3]Desalegn. T.

[1]Department of Environmental Studies, Florida International University

[2]South Florida Water Management District

[3]BEM systems

Abstract

The flow characteristic of the Blue Nile River (BNR) basin is presented. The study presents low and high flow, flow duration curve (FDC) and trend analysis of the BNR and its major tributaries. Different probability distributions were fitted to better describe the low and high flow of BNR at Bahir Dar. Flow duration curves were developed and low flow (below 50% exceedance) and high flow (over 75% exceedance) of the curves were analyzed and comapared. The Gravity Recovery and Climate Experiment (GRACE) satellite-based water equivalent monthly maps from 2003-2006 for February, May and September showed an increase in the moisture influx in the BNR basin for the month of September and loss of moisture in February and May. It was also shown that 2004 and 2005 were drier with less moisture influx compared to 2003 and 2006. Based on the Kolmogorov-Smirnov, Anderson-Darling and Chi-square tests goodness of fit, Gen. Pareto and Gen. Extreme Value and Gumbel Max distributions best describe the low and high flows within the BNR basin. This will be beneficial in developing flow hydrographs for similar ungauged watersheds within the BNR basin. The below 50% and above 75% exceedance on the FDC for five major rivers in addition to BNR showed different characteristics depending on size, land cover, topography and other factors.

Keywords: Blue Nile River, low and high flow, PDF, GRACE, flow duration curve, trend analysis

Ground Water Flow Simulation of the Lake Tana Basin

[1]Chebud, Yirgalem A., [2]Melesse, A.M.
[1]Department of Earth Sciences, Florida International University
[2]Department of Environmental Studies, Florida International University

Abstract

Understanding groundwater flow in the Lake Tana basin is key for estimation of hydrogeological parameters and quantification of water resources. With the intention to capture the groundwater contribution into Lake Tana, a case study was conducted at the Gumera River sub-basin, one of the five sub-basins that drain into the lake. The Gumera sub-basin was delineated using flow direction and stream definition processing from 90-m SRTM elevation grid using ARC-Hydro GIS tool. The sub-basin boundary, which is the dividing line of the groundwater flow into and out of the other watersheds, and the stream outlets are used as boundary conditions. Streams are used as internal drainage lines in the ground water modeling. The initial conditions were considered from the seasonal changes of flow differentiating them as wet and dry conditions. Following the basin's geological information, unconfined flow condition is considered and the model was processed using ModFlow 2002 software. In this study, a parametric approximation based on experts experience is used for this purpose. The result indicates that hydraulic head contours are aligned to the streams showing their relationship as a subdued form of the surface water flow which are dictated by the watershed shape. It specifically depicted that groundwater flow follows the surface water outlet. Specifically, the study indicated the need to estimate groundwater inflow from the flood plain while the contribution from the watersheds is streamlined across the surface flow channels. In other words, separate estimation of the subsurface flow from the 20 km stretch of the flood plain was found vital. The contribution from the flood plain is conceptualized by transient flows of unconfined aquifer which is contrary to the steady state flows of the contributing sub-basins. This was justified by the long flooding period and surface level groundwater rise observed in the plain. The result has shown that 16,000 m^3/day is flowing across the

perimeter of the Lake Tana. This could also partly justify the sustained dry season flow of the Blue Nile at the outlet of the lake in Bahir Dar. Four monitoring wells though spatially skewed in the low and mid-altitudes, are used as analytic elements that regulate the head distribution. The well hydrograph has been in agreement with the pumping rate assumed for consumption by the community. The study has given clues to further validate for any inverse method of parametric and flow estimation.

Keywords: Lake Tana, groundwater, modeling, Blue Nile, MODFLOW,

HYDROLOGICAL BALANCE OF LAKE TANA, UPPER BLUE NILE BASIN, ETHIOPIA

Abeyou Wale [a], Tom Rientjes [b], Ambro Gieske [b], Remco Dost [b], and Seleshi Bekele [c]

[a]Bahirdar University, Water Resource Engineering Department, Ethiopia.

E-mail: abeyouwale@yahoo.com

[b]Department of Water Resources, ITC, Enschede

[c]International Water Management Institute, East Africa Office, Ethiopia

ABSTRACT

Lake Tana's hydrological system shows a gap with respect to major lake water balance components where 48% of the catchment is ungauged. In this paper daily lake level is simulated giving due emphasis on runoff from ungauged catchments using rainfall-runoff and spreadsheet water balance model. Daily flows from ungauged catchment are estimated by transferring model parameters of gauged catchments using semi-distributed conceptual model HBV. Calibrated model parameters of gauged catchments with a relative volume error less than ± 5% and Nash-Sutcliffe coefficient greater than 0.6 are transferred to ungauged catchments based regional model, spatial proximity and catchment area, the result of ungauged flow simulation indicates that 42%, 47% and 46% of the inflow is coming from ungauged catchments respectively. A recent bathymetric row data collected on the lake was interpolated by incorporating 450 sample control points along the perimeter of the lake and islands with final burning to SRTM DEM. Lake area rainfall is estimated by inverse distance interpolation method resulting 1290mm/year (1992 to 2003), open water evaporation of the lake is estimated by Penman combination equation shows 1960mm/ year. Daily lake level simulation of the lake with ungauged flow estimation by regionalization shows a good performance with a relative volume error of 1.6% and Nash-Sutcliffe of 0.9 compared with observed lake level, which shows runoff from ungauged catchment to be 880mm/year (1995 to 2001). Sensitivity analysis of the lake level shows Lake Tana is highly sensitive to Lake Basin rainfall change, river inflows and evaporation respectively.

Key words: HBV, Regionalization, Lake Tana, Bathymetry, Water balance

Modelling Erosion and Sedimentation in the Upper Blue Nile

[1]Steinhaus, T., [2]Awulachew, S.B., and [3]Easter, Zach.

[1]Cornell University, USA, tss1@cornell.edu

[2]IWMI regional Representative, Sub-regional Officer for Nile Basin & Eastern Africa, Addis Ababa, Ethiopia, s.bekele@cgiar.org

[3] Cornell University, USA, zme2@cornell.edu

ABSTRACT

Abay Blue Nile contributes significant flow of water and sediment in the Nile. A better understanding of the hydrological characteristics, erosion and sediment runoff of different watersheds in the headwaters of the Nile River is of considerable importance because of the significant contribution of flow and water caused sedimentation. The need to improve and augment current development and management activities of these resources, especially in Ethiopia, where only 5% of surface water is actually utilized by Ethiopians, coupled also with heavy degradation and low productivity, but also high potential in hydropower and irrigation is paramount importance for socio-economic development in upstream in Ethiopia and sustainable operation of water infrastructure systems in the downstream in the Sudan and Egypt. This paper focuses in characterizing the runoff generated from various research catchments and tributary rivers, evaluate the rainfall-runoff-sediment relationships at various seasons and locations. The paper also attempts to evaluate the applicability of models such as SCS method and compares the performance with simple parameter models such as 2 parameter tan hyperbolic based monthly water balance and spreadsheet models. The result shows, unlike the temperate climate where rainfall is practically well distributed throughout the year, the monsoon type of regions where there are distinct seasonal rainfalls, the SCS method does not perform well. On the other hand the water balance models that use soil moisture accounting and saturation perform better. In similar manner, sediment in the rivers are occurring during the early period of the rainy season and peaks of sediment occur before the peaks of rainfall and discharge for a given rainy season.

Key words: Erosion, Sedimentation, Rainfall-runoff, Sediment Gauging

NON-LINEAR PARAMETERIZATION OF LAKE TANA'S FLOW SYSTEM

Ambro Gieske[1], Abeyou Wale Worqlul[2], Getachew Hadush Asmerom[3], Alemseged Tamiru Haile[1] and Tom Rientjes[1]

[1]ITC, Water Resources Division, Enschede, The Netherlands, gieske@itc.nl
[2]University of Bahirdar, Ethiopia
[3]Water Resources, Mines and Energy Bureau, Mekele, Tigray, Ethiopia

ABSTRACT

Lake Tana is a high altitude lake in the source area of the Blue Nile River with an area of about 3000 km^2, lying 1786 m above sea level. Its flow system is governed by four components: inflow from rivers into the lake, outflow at Bahirdar through the Blue Nile, direct rainfall on the lake and evaporation from the lake. Several water balance models were made recently, in which model parameters are usually determined by calibrating simulated lake levels against observed levels. These models are operating both on monthly and daily time steps. Solute mass balance based aproaches were included in the modeling recently. In this paper the lake's flow system parameters are identified by modeling average lake level fluctuations on a daily basis, using the observed inflow and outflow components together with the lake rainfall and evaporation. The volume-level and volume-area relations together with parameterized level-outflow curves, allow precise modelling of the lake level changes not only during the peak of the rainy season, but also during the period of recession just before the onset of the new rainy season.The modeling therefore gives a better insight into the natural behaviour of the lake during periods of both maximum and minimum levels. Through the non-linear parameterization an estimate is made of the so-called ungauged river flows. Finally, a study can be made of the system response to external forcing, such as for example natural variations in climate, peak rainfall periods, changes in outflow by man made structures.

Sediments Budget of the Nile System: A Geologic Perspective

Mohamed G. Abdelsalam
Missouri S&T
Department of Geological Sciences and Engineering
1400 N. Bishop Avenue
Rolla, MO, 65401
abdelsam@mst.edu

It is estimated that ~4,000 km^3 of fertile soil was deposited within the floodplain and delta of the Egyptian Nile since the river was connected to the rest of Sub-Sahara Africa Nile ~800,000 years ago. Much of this geological material was removed from Sub-Sahara Africa to be deposited within the Egyptian Nile which is controlled by the ~6 Ma old and ~300 meters deep Eonile Canyon. This canyon is topped with ~100 meters deep fertile soil layer (erosion products of the Ethiopian Plateau) overlying medium to coarse sand and gravel (erosion products of the Precambrian Red Sea Hill rocks), and deeper marine carbonates (deposited when the Missinian Salinity Crisis forced the Mediterranean water to extend as far south as the Sudanese-Egyptian boarder). Hence, a depositional rate of ~125 m^3/km^2/year is required to build the ~40,000 km^2 Egyptian Nile floodplains and delta assuming constant deposition rate and absence of tectonic disturbances. On the other hand, it is estimated that 93,200 km^3 of geological material was removed from the 250,000 km^2 catchement area of the Blue Nile since the beginning of its incision on the NW Ethiopian Plateau ~30 Ma ago. Steady incision rate yields ~12.5 m^3/km^2/year erosion rate since the beginning of the incision of the Blue Nile on the plateau ~30 Ma ago. This rate is only one-tenth of the deposition required to build the floodplains and delta of the Egyptian Nile. Erosion rate of the Ethiopian Plateau by the Blue Nile - deduced for the geological record – is also a fraction of the present day erosion rate within the Blue Nile catchment area estimated from river sediments load to be between ~125 and 490 m^3/km^2/year. The vast discrepancy between the depositional rate along the Egyptian Nile floodplain and delta, and the erosion rate of the Ethiopian Plateau by the Blue Nile can be explained by one or more of the following reasons: (1) Dramatic acceleration of incision of the Blue Nile in the Ethiopian Plateau since ~1 Ma resulting in an increased rate of erosion; hence increased amount of sediment flux received in Egypt. This is supported by recent studies which indicate that the incision rate of the Blue Nile on the Ethiopian Plateau has increased significantly in the past ~6 Ma. (2) The White Nile and the Tekeze-Atbara rivers might have equally been major supplier of sediments eroded from the Lake Plateau Region and the Ethiopian Plateau and deposited along the Egyptian Nile floodplains; (3) The time when the Egyptian Nile was connected to the Sub-Sahara Africa Nile is much older than the suggested ~800,000 years.